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ENGLAND AND WALES.

THE GEOLOGY OF THE
COUNTRY BETWEEN WHITBY AND SCARBOROUGH.

(EXPLANATION OF QUARTER SHEET 95 N.W.)

BY

C. FOX-STRANGWAYS, F.G.S., AND G. BARROW, F.G.S.

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PREFACE.

THE north-eastern parts of Yorkshire, with their admirably clear coast-sections of the Jurassic rocks, have been classic ground to the geologist since the first general sketch of their structure was published in 1815 by William Smith. From that date down to the present time they have been the subject of a voluminous literature. Smith himself elaborated his first outlines, and published a more detailed map of Yorkshire (1821). Shortly afterwards came the "Geological Survey of the Yorkshire Coast" by Young and Bird (1822), followed a few years later by Phillips' "Geology of the Yorkshire Coast" (1829). Of the numerous fossil mollusca obtained by various collectors from these shores, figures and descriptions continued to appear in Sowerby's "Mineral Conchology" (1812–1829), and furnished the first basis for palæontological comparison. The more recent contributions are too numerous to find even mention here. But reference may be made to the important labours of Blake, Davidson, Hudleston, Leckenby, Lycett, Morris, Simpson, Tate, Williamson, Wright, and others.*

The Maps, Sections, and Memoir, now published by the Geological Survey from original observation, afford some measure of the advance made in geological mapping since Smith's first masterly outlines were published, sixty-seven years ago. From the manner in which the Jurassic rocks of Yorkshire, as exposed on the coast line and in the interior, can be subdivided and traced, they present an admirable area for the study of geological structure and the relations of this structure to the forms of the ground. The quarter-sheet of which the following chapters are an explanation affords ample material for the prosecution of this study. Regarding the interesting estuarine character of the Lower Oolites, already discussed in previously published Memoirs (95 S.W. and S.E. and 96 S.E.), further information is here given, the whole series of strata being well developed in the district, and the marine bands being specially distinct. From an economic point of view much importance attaches to the ironstones of the Middle Lias. These are briefly referred to here, but fuller information regarding them will be given in the Memoir descriptive of the typical Cleveland district where the ironstone is so largely developed (Sheet 104 S.W. and S.E.)

ARCH. GEIKIE,
Director General.

9th October 1882.

---

* Full references to the literature of the subject will be given in a subsequent more general Memoir. It may be mentioned here that a list of published writings on the Geology of Yorkshire up to 1873 was appended by Mr. Whitaker to the 3rd Edition of Phillips' "Geology of the Yorkshire Coast" (1875), and that this List has been supplemented by Mr. J. W. Davis in the Proceedings of the Yorkshire Geol. and Polytech. Soc., N. S., vol. vi., pp. 198, 318, and vol. vii., pp. 97, 212, 319, 453.

NOTICE.

The survey of the area described in the following Memoir was conducted under the superintendence of Mr. H. H. Howell, District Surveyor. Mr. Strangways surveyed part of the Oolitic district; Mr. Barrow surveyed the Lias and part of the Oolites.

Mr. Barrow describes the Lias, the Oolites to the top of the Lower Estuarine Series, and the Whinstone Dyke. The Cornbrash and all the later Oolites are described by Mr. Strangways. The rest of the work is written by both authors jointly. The Lists of Fossils have been revised by Mr. Etheridge.

Eight of the corresponding six-inch maps of Yorkshire, wholly or partly comprised in this Quarter Sheet (95 N.W.; Sheet 44, New Series, of the Ordnance Survey), are published by the Geological Survey, viz.:—Sheets 32, 33, 46, 47, 62, 77, and 78. Sheets 61 and 76 are not intended for publication, but MS. coloured copies are deposited in the Office for reference. Sheet 67 of Vertical Sections illustrates the Lower and Middle Oolites of the Yorkshire Coast. Horizontal Section, Sheet 130, is engraving; others are in course of preparation.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.,
9th August 1882.

THE GEOLOGY

OF

THE OOLITIC AND LIASSIC ROCKS

BETWEEN WHITBY AND SCARBOROUGH.

CHAPTER I.

INTRODUCTION.

It is intended in this pamphlet to describe the geology of that part of the moorlands and seacoast lying between Whitby and Scarborough.

The map, although covering a land area of not more than about 88 square miles, includes some of the most interesting parts of East Yorkshire.

The only town of any importance is Scarborough, the south edge of the map just crossing the northern part of the town. There are, however, several villages of considerable size, the principal being Hackness, Scalby, Cloughton, and Burniston, in the neighbourhood of Scarborough; and Robin Hood's Bay, Fyling Thorpe, Aislaby, Sleights, and Sneaton, near Whitby.

The greater part of the area is wild moorland; but the numerous intersecting valleys are generally brought into cultivation, and are covered with small farms.

The principal rivers are the Derwent and the Esk. The former of these takes its rise in these moors, and flows south through the picturesque gorges of the Oolites to join the Humber; the latter, with its tributaries, flowing north and east to the sea at Whitby. The rest of the drainage of this district is carried on by the small becks which run down to the coast at Hayburn Wyke and Robin Hood's Bay. There is also an artificial branch to the Derwent, which takes the flood-water of that river, and, draining the low country near Scalby and Burniston, enters the sea at Scalby Ness.

The watershed dividing the drainage of the Derwent from that of the Esk rises to a height of 978 feet above the sea at Lilla Cross.

The rocks coming to the surface in this map comprise the whole series of the Middle and Lower Oolites as they occur in Yorkshire, and descend to beds well down in the Lower Lias.

The following are the geological formations which occur in the district:—

Table of Formations.

Post Tertiary	Recent and Post Glacial.		Alluvium. Peat.
	Glacial		Boulder Clay and Gravel.
Tertiary?	Igneous.		Basalt (Whinstone).
Secondary	Middle Oolite		Upper Calcareous Grit.
		Coralline Oolite	Upper Limestone and Coral Rag.
			Middle Calcareous Grit.
			Lower Limestone and Coral Rag.
			Greystone or Passage Beds.
			Lower Calcareous Grit.
			Oxford Clay.
			Kellaways Rock.
	Lower Oolite		Cornbrash.
		Inferior Oolite	Upper Estuarine Series.
			Scarborough or Grey Limestone.
			Middle Estuarine Series.
			Millepore Bed.
			Lower Estuarine Series, with 'Eller Beck Bed.'
			Dogger.
	Lias		Blea Wyke Sands.
			Upper Lias.
			Middle Lias.
			Lower Lias.

CHAPTER II.

LIAS.

Lower Lias.—In the district embraced by Sheet 95 N.W. the Lower Lias consists of a mass of dark argillaceous shales, slightly sandy, with hard marly bands in the lower part. It may be roughly divided on lithological and palæontological grounds into two parts, each of which may be subdivided into two zones or regions characterised by a distinct fauna. The only section which exposes any considerable portion of these beds is that in the cliffs and scars of Robin Hood's Bay. The following table is a summary of the rocks there seen:*

B. Soft shales with rows of ironstone doggers and pyritous nodules, 320 ft.	(*b.*) Soft shales with rows of ironstone doggers: *A. capricornus; Gryphæa obliquata.* (*Zone of A. capricornus.*)
	(*a.*) Soft shales with rows of pyritous nodules: *A. Jamesoni, Gryphæa obliquata, Pinna folium.* (*Zone of A. Jamesoni.*)

---

* This and all succeeding tables and sections are arranged in descending order.

A. Soft shales with a succession of sandy and marly bands, 140 ft.	(*b.*) Shales with hard sandy bands, the upper parts covered by fucoidal markings: *Gryphæa incurva* in scattered groups of 5 or 6; *Ammonites* abundant. (*Zone of A. oxynotus.*)
	(*a.*) Shales with marly calcareous bands, generally very shelly: *Gryphæa incurva; Hippopodium ponderosum* occurring in bands; *Ammonites semicostatus.* (*Zone of A. Bucklandi.*)

A. (*a.*) These beds, which form the zone of *A. Bucklandi* of Tate and Blake,* are only seen at low water, forming the series of outer scars in the bay, dipping in a direction at right angles to the coast line. The average dip is about 4°, and as the breadth of the outcrop is about 300 yards the thickness of rock exposed is about 60 feet, consisting of rather soft grey shales with harder sandy and somewhat calcareous bands interspersed. Near the shore *A. Turneri* is the predominant form, often accompanied by layers of *Hippopodium ponderosum,* whilst *A. semicostatus* is abundant on the further scars, *A. Bucklandi* being also found occasionally.

These scars are often so covered with weed that it is impossible to examine them, but at the end of a hot summer the weed dies and is washed away, so that the scars can be best studied in September and October. As, however, they are only exposed for any distance seaward at low spring tides, they are never very easily investigated. The following is a list of the chief fossils found here:—

Gryphæa arcuata, Lam.
Lima Hettangiensis, Terq.
Monotis inæquivalvis, Sow.
Pecten calvus, Goldf.
——— *Thiollierei,* Dumort.
——— *textorius,* Schloth.
Perna infraliassica, Quenst.
Cardinia hybrida, Stutch.
Protocardium oxynoti, Quenst.
Hippopodium ponderosum, Sow.
Leda galathea, D'Orb.
—— *Renevieri,* Opp.
Lucina limbata, T. and P.
Modiola lævis, Sow.
Nucula navis, Piette.
Pholadomya glabra, Ag.

Chemnitzia trivia, Tate.
Cerithium, sp.
Dentalium Etalense, Terg. and P.

Ammonites Bucklandi, Sow.
——— *semicostatus,* Y. and B.
——— *Turneri,* Sow.
Belemnites acutus, Miller.

---

* The Yorkshire Lias, by Ralph Tate and J. F. Blake. 8vo, Lond., 1876.

A. (*b.*) These beds consist of alternating layers of soft shale and bands of sandy marl, the latter being remarkable for the fucoidal impressions upon them, which are rendered visible by the action of the sea water. As a whole, these beds are not very productive of fossils, if we except *Ammonites*, which, both in variety of species and number of individuals, are more abundant here than in any other part of the Lower Lias in this district.

Besides being abundant the *Ammonites* of this group are very restricted in range, and occur in definite lines. The uppermost portion contains *A. armatus* and *A. densinodus* in considerable numbers. At about the middle of the beds there are two lines of small doggers or nodules, in almost every one of which the small *A. gagateus* occurs, often accompanied by small specimens of *A. oxynotus*. *A. Simpsoni* is also characteristic of this horizon. Towards the base, fragments of *A. saggitarius* are frequently found, and form another well-marked horizon in this group of beds; whole specimens are very rare.

A point of interest is the occurrence, about the middle of the series, of large lenticular discs of ironstone, usually unfossiliferous, with cone-in-cone structure developed in the lower part. They generally rest on a mass of broken crinoidal fragments, principally remains of *Pentacrinus tuberculatus*, in such a manner as to suggest the origin of the cone-in-cone structure immediately above. These discs are sometimes as much as 15 feet in diameter.

The highest of these beds of the *A. oxynotus* zone forms the scar opposite Bay Town, at which point they are dipping nearly due north; from this point southwards they rise into the cliff until near the middle of the bay, where the highest bed is about 90 feet above sea level, the beds now dipping nearly due west. The dip gradually changing to south, the strata descend till the bed that is opposite Bay Town forms part of the scar against the Peak fault, about 100 yards from the foot of the cliff. Thus we have two nearly complete sections, from which the following has been compiled:—

Section of *A. oxynotus* Beds, Robin Hood's Bay.

	Ft.	In.
Soft dark shales resting on hard sandy calcareous bed with fucoidal markings, *Gryphæa* and *Belemnites* -	1	0
Soft sandy shales: *A. raricostatus, A. armatus, A. dudresseri, Gryphæa obliquata* - - - -	5	6
Hard sandy band - - - - -	0	2
Hard sandy shale: *Rhynchonella variabilis* - -	5	6
Hard calcareous sandy band, forms the second well-marked scar *Modiola scalprum* - - -	2	0
Sandy shale with irregularly scattered discs of ironstone resting on crinoidal remains: *A. armatus*, several species of *Ammonites* in hard nodules - - -	8	6
Hard ferruginous sandy shale, almost an ironstone -	0	8
Hard sandy shale with crinoidal fragments - -	3	6
Hard shaly calcareous sandstone, fourth well-marked scar: *A. obsoletus* - - - - - -	0	9

	Ft.	In.
Sandy shale with many belemnite remains, harder at base. Fine specimens of *Gryphæa incurva*	5	6
Soft shale	0	2
Hard sandy band. This, with the two beds above, form a faint double line in the cliff, and a small terrace at the mouth of Mill Beck, where a considerable number of fossils may be obtained on the top of the terrace or ledge	0	10
Hard sandy shale	5	0
Softer sandy shale: *A. subplanicosta*	5	7
Shale, soft and grey, with a line of doggers at base containing *A. densinodus*, *A. raricostatus*, *A. impendens*, *A. Simpsoni*, *A. oxynotus*	10	0
Hard calcareous bed covered with fucoidal markings crosses the mouth of Mill Beck: *Pseudoglyphæa* (?)	1	3
Soft shale, with *Homomya ventricosa*	0	3
Hard calcareous band; this and the two above make a strong scar and a well-marked line in the cliff	0	9
Shale with remains of *Pentacrinus tuberculatus*, *Belemnites acutus*, *Modiola lævis*. At the base is a row of small doggers containing *A. gagateus* in great numbers, also *A. oxynotus*	7	3
Shale, soft and dark, with line of nodules at base, occasionally containing *A. gagateus*, *A. planicosta*	6	0

Below this point it is not easy to trace the scars into the cliff with any certainty; so that we may summarize the rest of the series as consisting of soft shales with occasional harder bands, the whole being about 35 feet thick. Throughout these shales fragments of *A. saggitarius*, a form closely resembling *A. Jamesoni*, are very abundant, but entire specimens are extremely rare. *A. obtusus*, *A. obsoletus*, *A. semicostatus*, and *Belemnites acutus* are also common forms. Tate and Blake* have included about 10 feet of shale with two hard bands, below the shales described above, in their zone of *A. oxynotus*, on account of the occurrence of *A. planicosta;* but the upper limit would seem the better marked physically.

The average thickness of these beds is thus about 110 feet.

B. (*a.*) The shales of this portion of the Lower Lias are essentially soft, dark, and argillaceous, particularly so in the lower part. The upper boundary, which is purely palæontological, is fairly marked by the sudden disappearance of *Pinna folium* and *A. Jamesoni*, as well as by the marked increase of the bands of argillaceous ironstone.

Bands of small ironstone doggers occur at intervals in the shales of the zone of *A. Jamesoni;* but, in the lower portion especially, their place seems to be taken by masses of *iron pyrites* in bands or lines; the mineral occurring in imperfectly formed tetrahedra. The abundance of *pyrites* is quite a characteristic feature of these shales; many of the smaller *Ammonites*, especially *A. densinodus*, being composed entirely of it.

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* Yorkshire Lias, p. 75. It will be found that the characteristic *Ammonites* often extend considerably above or below the position assigned them by these authors. This is especially the case with *A. armatus* and *A. capricornus;* the latter ascending into the *A. margaritatus* zone, and the former descending a considerable depth into the zone of *A. oxynotus*.

The entire series may be examined on the scars north-east of Bay Town, where the beds form a large flat expanse of shales, with fossils occurring, singly or in masses, at irregular intervals. These masses are calcareous, and consist chiefly of the shells of *Gryphæa*, *Pecten*, and *Belemnites*, in small, somewhat conical heaps; forming a feature that is characteristic of this part of the Lower Lias. The chief fossils which occur scattered are *A. Jamesoni* and *A. brevispina* in the upper beds; while *A. armatus* and *A. densinodus* are sufficiently common in the lower. *Pinna folium* occurs abundantly throughout; while *Gryphæa obliquata* is found in greatest profusion near the base. A remarkable point about this fossil is that while in the shales immediately above the *A. oxynotus* beds it is narrow and sulcate, much resembling the true *G. incurva*, the form gradually becomes more dilate, and the sulcus almost invisible, as it passes upwards towards the Middle Lias.

The following is a detailed section of these beds as seen in the cliff and on the scars of Robin Hood's Bay:—

	Ft.	In.
Grey micaceous shale - - - - -	3	0
Ferruginous nodular band - - -	0	4
Grey micaceous shale: *Gryphæa* and *Belemnites*, *A. Jamesoni* (?), *Protocardium truncatum* - -	5	0
Ferruginous doggers - - - -	0	3
Grey micaceous shale: *A. brevispina*, *Pinna folium*, *Gryphæa obliquata*, fossil wood, &c. - - -	5	0
Ferruginous dogger band with fossils - -	0	3
Grey micaceous shale - - - - -	5	0
Dogger band - - - - -	0	4
Grey micaceous shale - - - - -	2	0
Dogger band - - - - -	0	4
Black crumbly shale, with many fossils: *Belemnites elegans*, *Plicatula spinosa*, *Gryphæa*, &c. - -	9	0
Dogger band - - - - -	0	6
Dark grey argillaceous shale - - - -	3	6
Dogger band - - - - -	0	6
Dark shale - - - - - - -	1	2
Dogger band - - - - -	0	6
Dark argillaceous shale - - - - -	5	6
Dogger band, very persistent - - -	0	6
Dark shale*: *Pinna folium*, *Gryphæa*, &c. - -	6	0
Dogger band - - - - -	0	3
Shale, dark and argillaceous, with many scattered *Gryphæa*, *Pinna folium*, &c. - - - -	4	6
Nodular band - - - - -	0	3
Dark soft argillaceous shale, with large *Belemnites* -	3	6
Dark shale, weathers white, when dry - - -	15	0
Dogger band irregular.		
Dark argillaceous shale with crinoidal fragments and much scattered pyrites - - - -	3	4
Dark argillaceous shales with irregular patches of fossils - - - - - -	3	8

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* This bed enters the foot of the cliff, where it is intersected by a small fault.

	Ft.	In.
Fine grained shale with thin white lines (occurs at foot of first nab): *A. armatus, Belemnites, Pinna folium, Gryphæa obliquata*, &c.	10	0
Thick dogger band	0	7
Rather hard shale, layer of radiating pyrites at base	9	6
Softer shale with much pyrites: *A. densinodus*	5	0
Dark shale with flattened nodules	14	0
Dark shale with decomposed pyritous band	8	0
Compact shale, many *Gryphæa*	15	0
Shale with many doggers	15	0
About 30 to 40 feet of dark shales occur below this, containing many *Belemnites, Gryphæa*, &c.: *A. densinodus* in great numbers, *Lima pectinoides, Inoceramus dubius, Pleuromya Galathea* (?).		
Total	186	3

The only other exposures of this series are in the neighbourhood of Robin Hood's Bay, in the sides of the small streams that flow into it, such as Mill Beck; and in the base of the high cliff on the north-west side of the great Peak fault.

B. (*b.*) This series* consists of about 140 feet of grey micaceous shale, light coloured and sandy in the upper part, darker and more argillaceous in the lower. Perhaps the most characteristic feature of these beds is the occurrence of bands of ironstone doggers, often septariated, at intervals of a few feet. The septariated doggers constantly contain zinc-blende, and in many cases the prevailing *Ammonite* occurs as a cast entirely composed of blende. Some of these bands are very persistent, and can be traced as far as the beds of shale in which they occur are visible. Two in particular, a few feet apart, may be noticed, about 50 feet below the top of the Lower Lias; the upper one contains *A. fimbriatus*, while the lower is a thin seam of white speckled clay-ironstone, with a layer of small *Pectens* and *Belemnites* at the base.† Others, no doubt, are generally persistent, but have no sufficiently marked peculiarities by which they can be traced.

A complete section may be seen on the shore and in the cliff, showing the junction with the Middle Lias at the North Cheek, Robin Hood's Bay, and the gradual change, very slight, to the beds of the zone of *A. Jamesoni* below. The upper beds are rather hard, sandy, and micaceous, being also very regularly jointed. In consequence of this latter feature, large prismatic blocks, often nearly a ton in weight, fall from the face of the cliff; and in these blocks specimens of *A. capricornus* are fairly abundant, accompanied by (and sometimes included in) small round ferruginous doggers, which formerly were sometimes mistaken by the ignorant for cannon balls. An immense accumulation of such blocks may be seen at foot of the cliff on the north-west side of the Peak fault, the place from which they have fallen being inaccessible.

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* This division includes about 40 feet of the zone of *A. Jamesoni* of Tate and Blake.

† These two bands can be seen again at Staithes, and followed thence to Saltburn, 20 miles from Robin Hood's Bay.

As a whole, these beds are not productive of many fossils. One or two species, however, occur fairly abundantly in certain lines of doggers; such as *A. capricornus*, *A. fimbriatus*, and particularly the small *Pecten lunularis*.

The following detailed section was measured between the North Cheek and a point half way to Bay Town:—

	Ft.	In.
Thick band of *Gryphæa*, &c.: base of Middle Lias.		
Sandy shale, rather hard, with small doggers, enclosing *A. capricornus* - - - -	9	0
Thick dogger band, with occasional fossils -	0	6
Softer sandy shale with rows of very round small doggers - - - - - -	5	0
Dark shale, many scattered specimens of *A. capricornus* -	6	6
Shale, grey and micaceous - - - -	7	0
Shale, grey and micaceous - - - -	18	0
Shale with *A. fimbriatus*, *A. capricornus*, &c. - -	8	0
Small nodular band - - - -	0	3
Shale, light grey and micaceous - - -	10	0
Nodular band with cone in cone structure -	0	9
Shale with *Gryphæa*, *Belemnites*, &c. - - -	5	0
Shale, grey and micaceous - - - -	11	0
Dogger band - - - - -	0	6
Shale with *Belemnites*, *A. fimbriatus* - - -	8	0
Dogger band, impersistent.		
Shale, soft grey, with scattered doggers - - -	13	0
Shale, with *A. fimbriatus*, *A. Henleyi*, &c. - -	3	0

There are several exposures of these shales in the Robin Hood's Bay district; but, as a rule, they are difficult to examine, the streams passing over them cutting deep gorges with occasionally pools and small waterfalls, making many of the finest sections inaccessible. The upper part, with *A. capricornus* in the small round ironstone doggers, is well shown in Tan Beck, above the Peak Alum Works; and the junction with the Middle Lias above is also clearly exposed.

In Butcher Close Wood there is a gorge in black shale with flat ironstone doggers in bands, giving a clear section of nearly the whole of the *A. capricornus* beds, consisting of the dark bluish lumpy shales with iron-stained edges, and rows of ironstone doggers enclosing the typical *Ammonite*. A nearly similar section may be seen in the other branch, Mill Beck, of the former stream, a little below the new bridge on the road from Park Gate to Fyling Hall.

The only other sections of these beds are to be found in Eskdale, in the banks of the Esk between Sleights and Grosmont. The finest is at Blue Scar, so called from the exposure of these bluish-grey shales, where nearly 100 feet of them can be seen, with many rows of ironstone doggers. But beyond an occasional specimen of *A. capricornus* and a few small *Belemnites*, the steepness of the scar is so great that no fossils can be found. On the north bank of the river two small sections are exposed in the railway cuttings, close by the stream. The first shows several rows of small flat ironstone doggers in bluish shale; the second, south-west of the former, shows a lighter coloured and more sandy shale, with the basement beds of the Middle Lias above.

The following list of fossils from these beds at Robin Hood's Bay is from Tate and Blake (pp. 91, 92).

Wood.

Gryphæa cymbium, Lam.; *Var. depressa,* Phill.

Monotis inæquivalvis, Sow.
Crenatula (*Inoceramus*) *ventricosus,* Sow.
Modiola numismalis, Oppel.
——— *scalprum,* Sow.
Pholadomya Beyrichii, Schlönb.

Ammonites capricornus, Schloth.
———— *fimbriatus,* Sow.
———— *striatus,* Rein.

Middle Lias.—The Middle Lias of this district is divisible into two parts; the upper consisting of shales, with thin bands of ironstone of variable thickness, the lower of sandstones and hard shales, with sandy thick beds of *Gryphæa, Cardium,* &c., constituting a sandy marl.

The peculiar feature of the whole is the large quantity of iron occurring in the beds; either localized in bands, as in the upper series, or distributed throughout the mass, as in the sandstones, which often contain an average of more than 15 per cent. of iron. In both series of rocks the iron occurs in the form of Carbonate, which imparts a bright blue fracture to the stone when unweathered; indeed cases have been known of the sandstones of this lower series being mistaken for the main seam of ironstone, on account of their blue colour, especially when found at a considerable depth from the surface.

The lower part of the Middle Lias is now called simply "Sandy Series," as it seems better to abandon Phillips' term "Marlstone," which has been used to signify three entirely different series of strata; and which, moreover, is applied in the Cleveland district to all the beds between the Main Seam and the Lower Lias.

The beds of the Lower or Sandy Series are remarkable for the prodigious numbers of fossils, chiefly of a few species, which they contain. Of these *Cardium truncatum* is the chief; and if a new name were required for this division of the Middle Lias, "*Cardium truncatum* Sandstones" would probably be as good as any. In the lower part *Gryphæa cymbium* predominates, and is accompanied by *Avicula inæquivalvis*; calcareous bands near the base often consisting entirely of these two species. In one particular bed

Dentalium giganteum occurs in considerable numbers, while *Belemnites* and *Pecten* are tolerably abundant throughout.

The sandstone itself has a bluish tinge before exposure to the atmosphere; but as the iron and lime are slowly dissolved out, the stone often changes to a soft, close-grained, micaceous, flaggy sandstone; the flaggy structure being partly occasioned by the lines of shells. Upon splitting the stone open the faces are mostly found covered by casts of shells, principally *Cardium*, *Gryphæa*, *Pecten*, and *Avicula*. Where the sea has acted upon blocks of this sandstone, the salt water seems to rather harden the lime and iron; and thus the fallen blocks on the beach may be split up along the lines of fossils, and excellent small flags be obtained perfectly covered with *Pecten*, *Gryphæa*, &c., stained a rich red from the iron they contain. The paved footway down the hill to Bay Town is chiefly made of such fossiliferous slabs, which have first fallen from the cliff, then been hardened by sea-water, and finally carted away for flagstones.

The best section of these beds is just round the North Cheek of Robin Hood's Bay, and is as follows, in descending order:—

	Ft.	In.
Thin calcareous sandy band, forms the top of Dobson's Nab: layers of *Cardium truncatum*, &c.	0	10
Hard sandy shale	4	0
Calcareous sandy shale: *Dentalium giganteum*, *Gryphæa*, *Cardium truncatum*, &c. abundant	5	0
*Close-grained sandstone, ferruginous and calcareous, containing four distinct bands of *Gryphæa*, *Cardium*, &c.	3	0
Hard sandy shale with *A. margaritatus*, *Pecten*, *Belemnites*, &c. in bands	2	4
Dogger band	0	4
Hard sandy shale with an eight-inch fossiliferous nodular band at base	3	0
Hard shale, darker than above: *Pecten*, *Belemnites*, &c.	5	4
Calcareous and ferruginous dogger band: *A. capricornus*	0	6
Hard shale	0	6
†Very hard ferruginous sandstone, containing layers of fossils: *Dentalium giganteum* being very abundant in the uppermost; *A. capricornus*, *Bel. clavatus*, *Gryphæa cymbium*, &c. abundant; *Cardium truncatum* being found occasionally	4	6
Sandy shale with dogger band at base	4	10
Sandy shale with scattered fossiliferous doggers and fossil wood	10	0
Dogger band with fossils	0	3
Shale with band of septariated nodules at base	1	0
Shale with thin lines of *Gryphæa*, &c.	4	9
Shale with dogger band at base, almost composed of shells	2	8
Thin sandy laminæ, passing into a calcareous band composed of *Gryphæa cymbium* and *Avicula inæquivalvis*, accompanied by *A. capricornus*, *Eucyclus undatus*	—	
Rhynchonella calcicosta, *Belemnites*, &c.	1	6
Total	54	4

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[*] Forms the roof of Castle Chamber, a small hollow in the cliff at high-water mark.

[†] Forms the floor of Castle Chamber.

When measured with a rope the thickness was found to be about 60 feet; but as the cliff was not quite perpendicular 54 feet is probably nearer the truth.

Tate and Blake have objected to this base line for the Middle Lias, as passing through the middle of the zone of *A. capricornus.* But, in the first place, this is the line adopted by the Survey for the rest of England, and therefore must be carried on throughout; secondly, it is a line that can be accurately traced. It is impossible to map any boundary line between this and the top of the *A. oxynotus* beds, and as these latter hardly ever crop out in N. E. Yorkshire, we are practically without any well-marked division, or datum line for measurement, below the Ironstone beds. In addition, the sudden lithological change is accompanied by a very marked change in physical conditions; down to the base of the Middle Lias there is an abundance of Molluscan shells, whilst in the very uppermost portion of the Lower Lias there is a marked paucity of fossils. Hence this line is easy to trace, is warranted by physical reasons, is of practical utility, and moreover has been followed continuously throughout England.

The following is a list of the chief fossils observed in the section beyond the North Cheek, Robin Hood's Bay:—

Ophioderma Milleri, Phill.

Monotis inæquivalvis, Sow.
Pecten æquivalvis, Sow.
——— *lunularis*, Röm.
——— *substriatus*, Röm.
Gresslya lunulata, Tate.
Hippopodium ponderosum (?), Sow.
Leda minor, Simp.
Modiola scalprum, Sow.
Pholadomya ambigua, Sow.
Protocardium truncatum, Sow.

Dentalium giganteum, Phill.

Ammonites capricornus, Schloth.
——— *margaritatus*, Mont.

There are several exposures of these beds in the Robin Hood's Bay District. On the W. side of the Peak Fault the cliff is capped by the sandstones and sandy shale of this series. The pathway down to the great slip under the cliff at Peak is almost on the line of Fault, and to the left the sandstones are seen, containing the following species: *A. margaritatus, Hippopodium ponderosum, Cardium truncatum,* and *Gryphæa cymbium,* in abundance, *Dentalium,* &c. But as they are almost all casts this is not a good place for collecting. From this point the sandy beds make a well-marked terrace round the south-east side of the great amphitheatre of the Bay, and sink under the Boulder Clay beneath the Brow Alum Quarry.

It is impossible not to regret this covering of Boulder Clay; as nothing is more striking than the extreme symmetry of the south-east end of the Bay, where the beds crop out to the surface in a succession of curving terraces; whilst the north end, from its thick covering of Boulder Clay, seems almost shapeless. In this natural exposure of the beds several small sections may be seen, principally in the narrow but deep ditches that drain the fields; only in Tan Beck, however, is there a section of the whole of these sandy beds. The sandstones are cut through in the road at Susanna Hill; but westward of this we have no sections till we reach Butcher Close Wood, which is situated on the sides of the south branch of Mill Beck. Here the base of the Middle Lias is exposed; the section being as follows, in descending order:—

	Feet
Shale, hard and sandy	5
Sandstone, laminated, and full of casts of *Avicula inæquivalvis*, *Gryphæa cymbium*, and *A. capricornus*	3
Hard sandy shale almost white; dark shales with small ironstone doggers, and containing *A. capricornus*, for some distance down the stream	

Above this section the stream flows in Boulder Clay. In Mill Beck, about 100 yards west of the New Bridge, hard sandy shales with *Rhynchonella* and *Pecten lunularis* crop out, and from their lithological character we suppose them to be part of this series.

There are no more exposures in this district until we again reach the cliff, about 300 yards north of Bay Town; and from this point the beds fall gradually, till they finally reach the sea-level at Dobson Nab.

In Eskdale the first exposures are near Sleights, where the whole series may be seen and examined on the sides of the river. It is not possible to give an accurate detailed section, owing to the bank being often entirely covered by ivy and other creeping plants, which renders doubtful the tracing of each thin band. Near Woodlands a small stream cuts through the upper part of the series, and exposes, at the base of a small fall on the side of the Esk, hard sandy shales, with *Avicula, Gryphæa*, and occasionally *A. capricornus;* showing that this is near the base of the Middle Lias. On the opposite side of the river, a little further up, immediately under the railway, the lowest band of sandstone, with the characteristic "oyster beds," consisting of *Gryphæa cymbium* and *Avicula inæquivalvis*, may be seen rising from the river, dipping 3° slightly E. of N. The base of the series is seen again half a mile to the S.W. in the Beck below Eskdale Gate; but this section is very small, and entirely surrounded by Boulder Clay. A little further west the hard sandstone beds cap the great scar (Blue Scar) on the south side of the Esk. A complete section is here shown, but it is quite inaccessible for purposes of study

Several sections are exposed beyond the scar, especially in the stream flowing down from the old alum works, where the series may be measured, and gives a total thickness of about 60 feet.

Detailed measurements are of little value, as the sides of the streams are so steep that only the edges of each band of rock can be seen, and it becomes impossible to describe the fossil contents.

Upon comparing the sections at the various exposures of this division of the Middle Lias, it is easy to see that there is a typical form which will always represent the section, which is as follows:—

(*a.*) Upper part, consisting of two hard thin bands, with about four feet of shale beneath each.
(*b.*) Main mass of sandstone, with many bands of Cardium, &c.
(*c.*) Thick bed of hard sandy shale, with thin beds of sandstone in it.

This section never varies in type, and we maintain that there cannot be any doubt as to the absolute continuity of the two thin hard bands in the division (*a*). This is a very important point, as the upper of these bands becomes one of the chief datum lines for correlating the different seams of ironstone in Cleveland.

Ironstone Series.—To the upper division of the Middle Lias in Yorkshire, Prof. Phillips has given the appropriate name of Ironstone Series, from the occurrence in it of seams of ironstone, sometimes of considerable thickness. In the district embraced by the Quarter Sheet 95 N.W. the series consists of shales with thin bands of ironstone; these shales being soft and argillaceous in the upper and middle portions, harder and sandy in the lower; the whole being very prolific is fossils.

A complete section can be seen at Hawsker Bottoms, and is as follows:—

	Ft.	In.
(I.) Layer of earthy ironstone, weathering into rounded doggers: *Pecten æquivalvis* (large), *Belemnites breviformis, Pholadomya ambigua*, &c. - -	0	3
(II.) Shale, yellow-tinged, soft and finely laminated -	2	6
(III.) Ironstone dogger band; uneven top, very fossiliferous: *Pecten æquivalvis* (large), *Belemnites, Ammonites spinatus, A. ferrugineus, Modiola scalprum, Avicula inæquivalvis, Dentalium elongatum, Pholadomya ambigua, Cardium truncatum, Rhynchonella tetrahedra* in nests,* &c. - -	0	5
(IV.) Band of finely laminated shaly sandstone, cemented by carbonate of lime and iron, having the fracture of an ironstone (the *Indurated Shale Band*): *A. spinatus*, &c. - - - -	1	6
(V.) Grey shale, finely laminated, with sandy streaks and occasional ironstone doggers: *Pholadomya ambigua* and broken specimens of *A. spinatus*, &c.	6	0
(VI.) Continuous band of ironstone of irregular thickness: fossils as in No. (III.) - - -	0	6
(VII.) Shale weathering to small pieces, with occasional ironstone doggers - - - -	6	10

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* This is quite a characteristic feature of this band, wherever it can be examined.

	Ft.	In.
(VIII.) Ironstone band with many fossils, especially *A. spinatus*	0	3
Base of high scar at Hawsker.		
(IX.) Shale	1	0
(X.) Ironstone band, crowded with fossils: *A. spinatus*, *A. ferrugineus*, large *Pecten*, &c., very abundant; several species of *Gasteropods*, &c.	0	4
(XI.) Hard shale	4	6
(XII.) Strong band of ironstone, very fossiliferous	0	6
(XIII.) Hard dark shale, slightly sandy	3	6
(XIV.) Scattered dogger band	0	3
(XV.) Shale	2	5
(XVI.) Continuous band of ironstone	0	6
(XVII.) Shale, with large *Pecten æquivalvis*, &c.; base of *A. spinatus* zone	5	6
(XVIII.) Continuous band of ironstone, oolitic grains, *Myacites*, &c. - 6 in. Dark micaceous shale, large *Pecten*, *Belemnites*, &c. - 8 in. Hard grey ironstone - 4 in. “Pecten Seam”	1	6
(XIX.) Shale, hard at base, with *Pecten*, &c.	2	0
(XX.) Ironstone dogger band	0	2
(XXI.) Shale, with long flat doggers at base	2	4
(XXII.) Shale, slightly sandy, and containing aggregations of *Pecten*, *Belemnites*, *Gryphæa cymbium*, *A. margaritatus* (*A. Clevelandicus* of Simpson), &c.	18	0
(XXIII.) Ironstone band, with shale parting in the middle	1	5
(XXIV.) Shale, more sandy than above, small scattered doggers containing *Pecten lunularis* and *A. margaritatus* (?) in large numbers	15	0
(XXV.) Sandy ironstone, resting on a hard sandy band similar to the “*Indurated Shale Band*”: *Gresslya intermedia*, *Cardium truncatum*, &c. abundant	1	0
(XXVI.) Shales, very hard and sandy in lower part, softer in the upper, with thin bands of ironstone: Large *A. margaritatus*, *Cardium truncatum*, &c.	20	0
Total	98	2

At one point, where the cliff is nearly vertical, the entire series was found to measure 103 feet, so that 100 feet may be safely considered the average thickness in this district.

The only other exposure of this series on the coast is at the Peak Steel, where the base forms a hard triangular piece of rock between the two branches of the Peak fault, whilst the top of the series is on the other side of the eastern branch of this fault. Inland there are several small exposures of these beds in the south-east end of Robin Hood's Bay, chiefly under the Peak Alum Works, and along the railway cutting under the Brow. In the latter, flattened nodules, with *A. margaritatus*, may be seen at the base of the cutting, while the doggers in the upper part contain the large *Pecten* in abundance. From the nearness of the section to the Jet holes, the *Spinatus* series are probably at the top of the cutting, and consist of soft marly shales of a somewhat mottled appearance, containing doggers, the interior of which is usually filled with liquid mud. *A. spinatus* was not seen. In the narrow gorge of Howedale Beck there is a complete section of the Ironstone Series to a depth of about 80 feet. From this it is evident that the ironstone seams have entirely died out; bands of nodules, at some intervals, being the only representatives of the thick ironstones of the northern area. The shales, too are more argillaceous and decidedly less sandy than in the other sections. The top of the series is here well defined by a band of nodules, with the large *Pecten* and *Pholadomya ambigua: A. spinatus* was not seen. At some depth below, the nodules occasionally contain the small *A. margaritatus* (the *A. Clevelandicus* of Simpson), but the lowest beds seen are not so low down as the shales with the larger *A. margaritatus*, and hence the series must be about 120 feet thick.

From this point, till Hawsker is reached, the outcrop is entirely concealed by Boulder Clay; with the single exception of a small exposure in the south bank of Ramsdale Beck, where about six feet of soft shale, with a band of ironstone doggers, are seen. The fossils are of Middle Lias age, and probably belong to the middle of the series.

In Eskdale the ironstone bands, two in particular, have become considerably thicker, so much so as to have been mined for ironstone; but in the area included in 95 N.W. the mines have now been abandoned.

In that part of the Eskdale district under discussion there is no one complete section of the ironstone series, so that the following account has been compiled from three different places, one just beyond the western edge of the map.

Section in the Eskdale District.

	Ft.	In.		Ft.	In.
(I.) Ironstone band of irregular thickness, resting on the "*Indurated Shale Band.*"				1	6
(II.) Soft ferruginous shale with scattered ironstone doggers and many small fossils, *A. spinatus*, *Pholadomya*, large *Pecten*, &c.				5	0
(III.) Continuous band of ironstone				1	0
(IV.) Shale, dark and ferruginous				3	0
(V.) Ironstone band				0	10
(VI.) Shale				5	6
(VII.) Dogger band				0	4
(VIII.) Shale				6	0
(IX.) Ironstone band				1	0
(X.) Hard dark shale				6	0
(XI.) Ironstone	0	6	"Pecten Seam"	3	7
Shale	1	3			
Ironstone	1	10			
(XII.) Shale				27	0
(XIII.) Ironstone, "Avicula Seam"				2	0
(XIV.) Shale somewhat sandy				5	0
(XV.) Band of hard sandy shale				0	6
(XVI.) Hard shale somewhat sandy				25	0
				93	3

Or 90 feet very nearly, as the detail measurements are usually rather exaggerations.

In comparing this section with that at Hawsker (pp. 13, 14) there are at least three, and probably four, bases for measurements. Of these the first is the "Indurated Band,"—No. IV. at Hawsker, and No. I. in Eskdale; the second is the "Pecten Band" (Nos. XVIII. and XI.); and the third is the base of the series, which is in both cases a bluish coloured marly sandstone. In addition to these there can be little doubt but that the "Hard sandy band" (No. XXV. at Hawsker) is the same bed as No. XV. seen in the Esk.

From this we may infer that the ironstone thins away going from Eskdale in a south and east direction; while the argillaceous shales increase (in thickness), the sandy shales on the other hand appearing to diminish slightly.

There are several exposures of the Ironstone Series in Iburndale; the most southerly being in the bed of Little Beck, at Shaw Head, where the upper part and its relation to the Upper Lias may be well seen. The bank above, on the west side of the stream, consists of soft Grey Shale, with decomposed earthy nodules, while near the base there is a small row of ironstone doggers with *Pholadomya ambigua.* Two feet below this is the representative of the "Indurated Shale Band," so well developed at Hawsker, but which here consists merely of sandy micaceous laminæ, and is about three inches thick.

Further down the stream at Throstle Nest, and again a few hundred yards further north, the *Pecten Seam* crops out, the following being the section:—

	Ft. In.		Ft. In.
Ironstone - -	0 10	*Pecten Seam** -	2 4
Shale - -	0 4		
Ironstone - -	1 2		

Below this is a bank of shale with several thin ironstone dogger bands, the whole about 20 feet in thickness.

The section here is not cut to a sufficient depth to show the *Avicula Seam,* but the rock next exposed further down the stream consists of the rather hard sandy shales below it; while the seam itself may be seen at the first sharp bend in the stream below Iburndale village, and again, dipping sharply north-east, at the railway bridge. Here the section is:—

			Ft. In.
Shales, ferruginous and lumpy - - -			8 0
Hard ironstone - - -	0 10	*Avicula Seam*	2 0
Softer stone, shelly in upper part	1 2		
Total - - - -			10 0

A small stream that flows down the east bank of Iburndale from Ugglebarnby exposes part of the Ironstone Series, probably just above the *Pecten Seam,* as a trial hole has been driven in, exposing now only the top of a seam of ironstone, which however has not been worked.

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* This will not be so thick further from the outcrop.

On the north side of the Esk, opposite Sleights Bridge, a shaft was sunk about 30 feet to a seam of ironstone, probably the *Pecten Seam;* which was worked for several years, and about 11,000 tons were produced after which the mine was abandoned. The seam was three feet thick, with a shale parting of one foot in the middle. In the north bank of the river, a little further west, both seams crop out; but the ground is so much obscured by vegetation and clay that it is impossible to give a detailed section of them. From this point the middle of the Esk valley is completely covered with Boulder Clay and Gravel, to a depth in some cases of 200 feet, so that the position of the Ironstone Series can only be conjectured. On the south bank, however, there are several exposures, the seams being also proved by mining at Eskdale Gate. The section here is given in the Section of the Ironstone Series in Eskdale (p. 15), the *Pecten Seam* being,—

	Ft.	In.
Ironstone - - - - - -	0	6
Shale - - - - - -	1	3
Ironstone - - - - - -	1	10
	3	7

The *Avicula Seam* consists of a solid block of ironstone, two feet thick.

A few small exposures occur in the hollow between Caley House and the old Alum Works; and both seams have been tried immediately under the new Alum Works. But in all these cases the seams have proved too thin and too poor in quality to be long worked at a profit.

The following is a list of the chief fossils from the Ironstone Series in this district.*

FOSSILS FROM HAWSKER BOTTOMS.

Zone of A. spinatus.

Fucoid markings?

Rhynchonella.

Inoceramus sub-striatus, Münst.
Gryphæa cymbium, Lam.
Monotis inæquivalvis, Sow.
——— *calva,* Schlönb.
Pecten æquivalvis, Sow.
Limea acuticosta, Münst.
Pleuromya rostrata, Ag.
Leda Galathea, D'Orb.
—— *graphica,* Tate.
Modiola scalprum, Sow.
Pholadomya ambigua, Sow.

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* Tate and Blake, pp. 109, 126, 127.

Astarte.
Unicardium sub-globosum, Tate.

Dentalium elongatum, Münst.

Ammonites spinatus, Brug.
——— *ferrugineus,* Simp.
Belemnites breviformis, Voltz.

and many small shells, Gasteropods, &c.

Fossils from Hawsker.

Zone of A. margaritatus.

Wood.

Pecten æquivalvis, Sow.
Monotis (*Avicula*) *cygnipes,* Y. and B.
Plicatula spinosa, Sow.
Pleuromya costata, Y. and B.
Cardita multicostata, Phill.
Ceromya petricosa, Simp.
Gresslya intermedia, Simp.
Modiola scalprum, Sow.
Protocardium truncatum, Sow.

Ammonites margaritatus, Montf.

Upper Lias.—The Upper Lias is essentially a thick bed of shale, chiefly argillaceous, and generally of a grey colour, getting nearly black in the lower part; its thickness is extremely constant, being 240 feet very nearly. It may be roughly divided into three parts: (*a*) the highest division—soft grey micaceous Alum Shale, with *Ammonites communis, A. elegans, A. bifrons,* &c., and *Leda ovum,* "jet rock" occurring at the base; (*b*) hard dark shale with pyritous doggers, the characteristic forms being *A. serpentinus* and *Inoceramus dubius;* (*c*) the lowest division—soft shale or grey shale, with the very restricted form *A. annulatus.*

The following more detailed section was measured between Whitby and Saltwick, except the lower part, which is only seen in the cliff at Hawsker.

	Ft.	In.
Shale, soft grey and micaceous, with cement doggers in the first 18 feet: *A. communis, A. elegans, A. bifrons, Leda ovum,* &c., abundant; *Myacites donaciformis, Nautilus striatus, Belemnites vulgaris,* &c. - -	34	0
Hard ferruginous shale band - - -	0	4
Shale, soft grey and micaceous: fewer fossils - -	19	0
Lumpy calcareous band: *Leda ovum* well preserved, *Lingula,* &c. - - - - -	0	4
Shale, similar to above, but slightly harder at base -	20	0
Band of hard shale - - -	0	3

	Ft.	In.
Shale, harder and darker; the beds above to the base of this are used for making alum* (Alum Shale)	20	0
Double band of pyritous doggers with *A. ovatus*:—		
Hard blue-black shale, with slight bituminous odour: large *Inoceramus dubius*	18	0
Hard black shale, similar to above, thin band of pyritous doggers at base	10	0
Hard black shale, bituminous; band of pyritous doggers, with casts of *Inoceramus dubius* (*small*) on the exterior	24	0
(*This band is at the base of Saltwick Nab, and by the dip there will be between the Nab and low-water mark,*)		
Hard dark bituminous shale	30	0
Jet Rock, hard platy rock, with thick dogger at top; source of all the *Hard Jet*	25	0
Soft shale or grey shale	30	0
Total of Upper Lias	231	0

Owing to the Jet Rock being important as the source of a valuable mineral, it is mapped wherever possible; this course being rendered more easy by the strongly marked lithological and palæontological characters of the bed.

The Grey Shale, or soft shale, is the bed that rests immediately on the Ironstone Series; and consists, as its name implies, of a shale that weathers soft and grey. It contains bands of earthy impure ironstone, two of which occur close together about the middle of the bed, enclosing *Ammonites annulatus*, the characteristic fossil, in great abundance; *Belemnites cylindricus* occurs at about the same horizon. These two characteristic fossils are found occasionally in the lower part of the shale, accompanied by a few shells of Middle Lias type, apparently dwarfed. With these slight exceptions the Grey Shale is remarkable for the paucity of its fauna, especially when contrasted with the beds above and below. Owing to its forming a hollow, from its soft nature, sections in this part of the Upper Lias are rather rare, the only good one being at Hawsker Bottoms. The Grey Shales crop out at Peak; but they have been worn into a hollow, since filled up with loose blocks of Oolite sandstone, and always more or less covered by water.

They can be fairly well seen in Howedale Gorge, but are rather inaccessible. The other exposures are:—In the stream near Littlebeck; at the bottom of Battlebanks; and in the little stream or ditch by the road-side at Sleights' Bridge.

List of Fossils from the zone of Ammonites annulatus:—†

Extracrinus Briareus, Mill.

Elytron of Coleopterous Insect.

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* This shale was calcined, and sulphate of alumina obtained by steeping the burnt shale in water; potash was then added to make alum, sulphate of alumina, and potash.

† Tate and Blake, p. 172.

Rhynchonella Jurensis, Quenst.

Inoceramus dubius, Sow.
Lima Galathea, D'Orb.
Monotis inæquivalvis, Quenst.
——— *papyria*, Quenst.
Pecten substriatas, Röm.
——— *æquivalvis*, Sow.
Pinna spathulata? Tate.
Pleuromya rotundata, Zeiten.
Protocardium truncatum, Sow.
Macrodon intermedius, Simp.
Cypricardia cucullata, Goldf.
Goniomya hybrida, Münst.
Gresslya intermedia, Simp.
Leda Galathea, D'Orb.
Modiola numismalis, Oppel.
——— *scalprum*, Sow.
Nucula subglobosa, Röm.
Pholadomya ambigua, Sow.
Unicardium subglobosum, Tate.
Astarte striatosulcata, Röm.

Actæonina tessellata, Tate.
Chemnitzia Blainvillei, Münst.
——— *acuta*, Tate.
Cerithium liassicum, Moore.
Dentalium elongatum, Münst.
——— *liassicum*, Moore.
Eucyclus cingendus, Tate.
Pitonillus turbinatus? (cast) Moore.
Turbo cyclostoma? (cast) Benz.

Ammonites annulatus, Sow.
——— *concavus*, Sow.
——— *margaritatus*, Montf.
——— *cornucopia*, Y. & B.
——— *semicelatus*, Simp.
Belemnites, cylindricus, Simp.
——— *latisulcatus*, Phill.
——— *breviformis*, Voltz.
——— *pollex*, Simp.
——— *validus*, Simp.
——— *striolatus*, Phill.
——— *scabrosus*, Simp.

Ichthyosaurus sp.

The Jet Rock.—This division of the Upper Lias is well contrasted with the bed below, being remarkable for its even bedding, splitting into long thin laminæ, and for the abundance of fossils in it. It is of a dark colour, and contains many rows of small round or oval pyritous doggers, usually covered with casts of *A. serpentinus* and *Inoceramus dubius* on the outside; or containing them, generally well preserved, inside. In this latter case the Ammonite will often be found to contain liquid bitumen in the chambers. The nodules have only a pyritous skin or coat, the interior being a blue cement-stone having a powerful odour of mineral oil. At the top of the Jet Rock is a continuous band of doggers, which may be well seen at Saltwick, at low tides; they are sometimes as much as 15 feet in diameter, and very hard, being composed of sandy shale in long thin plates, cemented together by carbonate of lime and iron. This continuous dogger-band forms the roof to all the workings for Hard Jet,* as it occurs in greatest quantity for about 10 feet below this band.

In addition to the two fossils mentioned above, *A. elegans*, *A. heterophyllus*, *A. gracilis*, and *Belemnites tubularis* are tolerably abundant; a pecularity of this bed being the great number of Cephalopoda as compared with other molluscs. Our knowledge of the fauna of this rock has, of course, been greatly increased by the jet-mining; remains of saurians and fish, particularly *Lepidotus semiserratus*, being frequently met with in consequence.

The Jet Rock can be seen, nearly covered by débris, at the foot of the Peak cliff, on the east side of the fault. From this point it is thrown up immediately below the Peak Alum Works, where it has been extensively mined along the face of the hill. At Stoupe Brow it is covered by a thin coat of Boulder Clay, but it emerges further west, and has been much wrought in Howedale. Beyond this point its outcrop is completely hidden till it reaches the North Cheek, after which it soon appears in the face of the cliff, forming the cap-rock at Nigh and Far Jetticks. Its position in the cliff-face is marked by the terrace still left (where the Jet shales have been dug away) till it reaches the shore, in consequence of the northerly dip, at Hawsker Bottoms. Here the bed can be very conveniently studied and measured, its thickness being between 25 and 30 feet.

The long white line of breakers that extends at almost all tides from Black Nab to Saltwick, is caused by the top of this rock; the lenticular doggers, of calcareous and ferruginous shale, being here very hard and of enormous size. At very low tides the breakers caused by this bed can be clearly seen from the top of the cliffs in the form of a curve stretching west till it is due north of the Old Abbey.

Inland the Jet Rock has been mined below the Alum Works in Eskdale, and also near Throstle Nest and Littlebeck, in Iburndale.

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* This jet appears to be formed of water-logged coniferous wood, from which in a few rare cases all trace of structure has been removed.

List of Fossils from the Jet Rock.

[*]*Inoceramus dubius*, Sow.
[*]*Posidonomya Bronnii*, Voltz.

[*]*Ammonites elegans*, Sow.
[*] ——— *serpentinus*, Rein.
[*] ——— *heterophyllus*, Sow.
[*] ——— *delicatus*.
[†] ——— *bifrons*, Brug.
[†] ——— *Mulgravius*, Y. and B.
[†] ——— *ovatus*, Y. and B.
[†]*Belemnites lævis*, Simp.
[†] ——— *tripartitus*, Schloth.
[†] ——— *tubularis*, Y. and B.
[†] ——— *subtenuis*, Simp.
[†] ——— *Volzii*, Phill.
[†] ——— *vulgaris*, Y. and B.
[*]*Gyrosteus mirabilis*, Ag.

Alum Shale.—The Alum Shale and the hard shale to the top of the Jet Rock are first seen rising from the sea at Blea Wyke, capped by some soft dark sandy shale, to be described presently. It is here probably rather thicker than usual, the average being about 145 to 150 feet. Of this, the upper 100 feet consists of soft grey micaceous shale, weathering to small crisp fragments with yellow edges, the source of the Alum. They are characterised by the abundance throughout of *A. communis* and *Leda ovum*. The lower 50 feet is composed of harder and darker bituminous shale, not used for Alum, and in which *Ammonites* of the "*serpentinus*" type are predominant; *Inoceramus dubius* being also very abundant in the lower part. These beds continue to form the lower part of the great cliffs at Peak till the fault is reached, where the base of them coincides very nearly with the base of the cliff. On the west side of the Peak fault there are constant exposures of these shales, especially in the great abandoned Alum Works at Peak and Brow. The best inland section, however, is probably that of Howedale, where almost the entire series may be examined and measured in detail. Beyond this point the Boulder Clay creeps up the hill, and the Alum Shale is not seen again till Pretty House is reached, where there is a section a few feet below the Dogger, but not actually showing the junction of the two. The shale has been turned out by rabbits in the woods and fields on the north side of Ramsdale Beck; while several exposures may be seen in the deep ditches about Park Hill. At Row there is a waterfall cutting into the Alum Shale to a depth of about 10 feet, the Dogger forming the top of it; and under the old Fylingdales churchyard wall the top of the shale crop out.

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[*] Tate and Blake, p. 174.

[†] Phillips' Geology of the Yorkshire Coast, 3rd Ed., 1875, pp. 145–150.

At Bay Ness, and down the hill side, it can be plainly seen, as in many places there are not three inches of soil. The whole of the series may be measured, though not examined, at Normanby Stye Batts; and from Maw Wyke to Whitby the base of the cliff and the scars consist of this portion of the Upper Lias.

In Eskdale there is only one exposure on the north side of the river, the Dogger and about 50 feet of Alum Shale being seen in the small stream that flows down from Aislaby past Woodlands. On the south side there are several exposures; the first on the railway embankment in a plantation between Sleights and Ruswarp, where the top only of the shale is visible; and there are no more sections till reaching the small stream below the churchyard, Ugglebarnby, where shale can be seen about 20 feet down. In Iburndale the best sections are in Littlebeck Alum Works; on the banks of the stream below; in the neighbourhood of Falling Force; in Wash Beck; and at the Thorn Hill works. The Malton road passes over Sleights Brow, through a cutting in the lower and harder beds; while fine sections of the softer part may be studied in the Eskdale Alum Works.

List of Fossils from the Alum Shale.*

Eryon Hartmanni, H. V. Meyer.

Lingula Longoviciensis, Terq.
Discina reflexa, Sow.

Inoceramus cinctus, Goldf.
Ostrea subauricularis, D'Orb.
Hinnites papyraceus, Zeiten.
Pecten pumilus, Lam.
Monotis substriata, Zeiten.
——— *inæquivalvis*, Sow.
Arcomya elegans, Phill.
Gresslya donaciformis, Phill.
——— *rotundata*, Phill.
Thracia glabra, Ag.
Trigonia literata, Goldf.
Leda ovum, Sow.

Cerithium quadrilineatum, Röm.

Ammonites communis, Sow.
——— *Holandrei*, D'Orb.
——— *crassus*, Y. and B.
——— *Braunianus*, D'Orb.
——— *heterophyllus*, Sow.
——— *subcarinatus*, Y. and B.

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* Tate and Blake, p. 189.

Ammonites Desplacei, D'Orb.
——— *bifrons*, Brug.
——— *Levisoni*, Simp.
——— *subarmatus*, Y. and B.
——— *Lythensis*, Y. and B.
——— *elegans*, Sow.
——— *fibulatus*, Sow.
——— *fonticulus*, Simp.
——— *primordialis*, *Schloth.*
Belemnites vulgaris, Y. and B.
——— *lævis*, Simp.
——— *Levidensis*, Simp.
——— *Voltzii*, Phill.
Nautilus astacoides, Y. and B.
——— *Jurensis*, Zeiten.
Gyrosteus mirabilis, Ag.

Plesiosaurus homalospondylus, Owen.
——— *Cramptoni*, Carte. and Bailey.
——— *Zetlandi*, Phill.
Ichthyosaurus crassimanus, Owen.
——— *acutirostris*, Owen.
——— *longirostris*, Jager.
Teleosaurus Chapmanni, König.

CHAPTER III.

OOLITE.

Lower Oolites.

The whole series of the Lower Oolites crops out on the coast between Blea Wyke Point and Scarborough. Of this the lower portion is well exposed in the fine cliffs of Staintondale and Cloughton; but the upper beds have been removed by denudation, and are only obscurely seen in a few places in the cliff, and more generally on the shore below high-water mark, between Long Nab and Scarborough; they are also visible in the North Cliff, at which latter place the topmost beds appear in the lower part of the cliff.

They consist of a thick series of sandstone and shale, containing plant-remains and thin coals, deposited under estuarine and freshwater conditions, and separated into distinct horizons by four or five beds containing marine fossils; in fact the whole series is composed of a great alternating set of estuarine and marine beds.

There is an admirable section of the lower portion of this great series in the cliffs at Blea Wyke; where, from their situation, it is possible to examine carefully and measure almost every marked bed. The following section is a fairly accurate representation of these strata:—

Section of the cliffs at and near Blea Wyke.

		Ft.	In.
Moor Grit -	Massive false-bedded sandstone resting on flaggy sandstone - - -	40	0
Grey Limestone Series.	Sandy and calcareous shale resting on bands of impure limestone - -	100	0
Estuarine Series	Shales and false-bedded sandstone, with occasional beds of fireclay and a thin seam of coal in the lower part - -	100	0
Millepore Bed -	Nodular bands, with calcareous and ferruginous sandstone below - - -	8	0
Estuarine Series, with Eller Beck Bed.	Great masses of false-bedded ferruginous sandstone resting on shales, with bands of carbonaceous matter - - -	110	0
	Thin flaggy sandstone resting on a few feet of soft shale enclosing thin bands of ironstone; *Eller Beck Bed* - -	15	0
	Principally carbonaceous shales, with thin coal seams in the upper part, false-bedded sandstones in the lower - - -	150	0
Dogger - -	Sandstone, oolitic in parts, with layers of small pebbles, and weathering into rounded blocks with ferruginous casings; soft sandstone below graduating into the shales of the Upper Lias -	95	0
	Total - - -	633	0

Thus, at Blea Wyke, there are nearly 500 feet of rock between the base of the Grey Limestone series and the top of the Upper Lias; but these beds are not known to be so thick elsewhere. At Hawsker their entire thickness is not quite 300 feet; while near Ruswarp a boring,* commenced about 40 feet below the base of the Grey Limestone Series, shows the total of these estuarine beds to be about 280 feet.

The Dogger.—At the base of the Lower Oolites, in the district embraced by this Memoir, there usually occurs a bed of red sandstone, slightly calcareous and very ferruginous, so much so as to pass occasionally into an ironstone; the per-centage of silica is, however, in all cases so high that efforts to work it as a source of iron have been abandoned. It is known locally as the *Top Bed* or *Dogger*; the latter name being given to it in consequence of its mode of weathering to doggers, or roundish lumps enclosed in a ferruginous casing. It is usually a littoral formation, and a peculiar characteristic of the bed is the number of small nodules, or, as they are often called, pebbles,† that it contains.

This bed is first seen rising from the sea at Blea Wyke, a point on the coast about a mile S.E. of Robin Hood's Bay, where the following remarkable section‡ may be observed:—

	Ft.	In.
(I.) Dogger sandstone, hard, red, and ferruginous, with small projecting masses of oxide of iron; pebbles scattered throughout	10	0
(II.) Ferruginous band, composed entirely of shells, the lime nearly all replaced by iron; the "*Nerinæa band*"	1	6
(III.) Greenish dogger sandstone with pebbles, scattered and in bands	25	0
(IV.) Ferruginous shaly micaceous bed; very few fossils	1	2
(V.) Brown sandstone, crowded with *Terebratula trilineata*	2	0
(VI.) Soft brown sandstone, becoming yellow in lower part; fossils in nests, calcareous casts of large *alveoli* of *Belemnites*; pebbles scattered throughout	25	0
(VII.) Soft grey sandstone, forming a back to the scar; fossils in nests, "*Vermetus bed*"	10	0
(VIII.) Soft sandstone and hard grey sandy shale; fossils in nests, fossil wood, *alveoli* of *Belemnites*, &c.	25	0
(IX.) Soft grey sandy shales	7	0
(X.) Soft dark grey shales, with doggers; the uppermost dogger band being almost composed of *Lingula Beanii*; the thickness of the shales is doubtful	—	

The bed (I.) is in all respects the same as the Dogger when seen in other exposures in this district; but the beds below are lithologically distinct, and for the most part are not known to occur elsewhere.

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* Young and Bird's Geological Survey of the Yorkshire Coast, 2nd Ed., p. 124.

† It seems very doubtful if these are ever really pebbles. They are hard and dark externally, but have a soft whitish interior, and occasionally seem to be water-worn nodules from the Lias, as they frequently contain casts of Ammonites of a Liassic type.

‡ For further information on this important section, *vide* Tate and Blake, *Yorkshire Lias*, p. 19; Dr. Wright's paper, Quart. Journ. Geol. Soc., vol. xvi., p. 1; and W. H. Hudleston, Proc. Geol. Assoc., vol. iii., p. 293 *et seq.*

The fossils of bed (II.), known as the *Nerinæa band,* are as follows :—

Rhynchonella obsoleta, Sow.
Terebratula perovalis, Sow.

Hinnites velatus, Goldf.
Gervillia tortuosa, Sow.
Pteroperna striata, Bean.
Modiola cuneata, Sow.
Cucullæa cancellata, Phill.
Macrodon Hirsonensis, D'Orb.
Trigonia denticulata, Ag.
——— *V. costata,* Lycett.
——— *spinulosa,* Y. and B.
Cypricardia acutangula, Phill.
Tancredia axiniformis, Phill.
Cardium striatulum, Sow.
Opis Phillipsii, D'Orb.
Astarte elegans, Sow.
Ceromya Bajociana, D'Orb.
Gresslya adducta, Phill.

Natica adducta, Phill.
——— *punctura,* Bean.
Chemnitzia lineata, Leck.
Nerinæa cingenda, Bronn.
Cerithium (2 *species*).
Alaria Phillipsii, D'Orb.
Onustus pyramidatus, Phill.
Nerita lævigata, Phill.
Trochotoma.
Actæonina.

The above list proves these beds to be of undoubtedly Oolitic age.

(III.) This bed is a ferruginous sandstone containing a considerable per-centage of iron in the form of a carbonate, to which its bluish-green colour is probably due. The small nodules or pebbles are principally localised in bands, and the few small fossils that occur are mostly ferruginous casts.

(IV.) This bed is a ferruginous micaceous hard sandy shale ; it is nearly water-tight, so that it arrests the downward progress of the water through the beds above ; in consequence of which fossils found in this shale, of which there are not many, are mostly decomposed. The following are the chief recognisable forms :—

Terebratula trilineata, Y. and B.
Rhynchonella cynocephala, Rich.

Trigonia Ramsayi, Lycett.
Gresslya peregrina, Phill.

Belemnites compressus, Stahl.
——— *irregularis,* Schloth.

(V.) The *Terebratula* bed consists of two feet of soft brown or yellow sandstone crowded with fine casts of *Terebratula trilineata*, other fossils being mostly small and in nests. A careful examination of this bed and other sections of the Dogger almost necessitates the conclusion that this is the usual base of the Oolite in most cases, all the beds below being missing. There is no lithological distinction between this division of the Dogger and bed (VI.), in which the following fossils have been found:—

Glyphæa Birdi, Bean.

Avicula inæquivalvis, Sow.
Astarte.
Goniomya angulifera, Sow.
Trigonia.

Turritella.

Ammonites Comensis, V. Buch.
——— *insignis*, Schub.

(VII.) This bed of soft yellow sandstone is commonly known to geologists as the "*Vermetus* bed" or "*Serpula* bed," from its containing great numbers of *Vermetus compressus* and *Serpula deplexa*, a feature sufficient to at once distinguish the bed from the other parts of the Dogger. It contains a considerable number of fossils, of which the following are the chief:—

Serpula deplexa, Phill.
Vermicularia compressa, Y. and B.

Lingula Beanii, Phill.

Cardium striatulum, Sow.
Gresslya peregrina, Phill.

Dentalium elongatum, Münst.

Ammonites Aalensis, Zeiten.

(VIII.) This bed is a slightly shaly sandstone, passing gradually into bed (IX.), a hardish sandy shale. The following fossils are recorded by Tate and Blake in their *Yorkshire Lias*, page 19:—

Glyphæa Birdi, Bean.

Terebratula trilineata, Y. and B.
Rhynchonella cynocephala, Rich.
Discina reflexa, Sow.
Lingula Beanii, Phill.

Avicula substriata, Münst.
Gervillia Hartmanni, Sow.
Pecten silenus.
Pinna cuneata, Phill.
Cucullæa cancellata, Phill.
Gresslya peregrina, Phill.
Pholadomya fidicula, Sow.

Cerithium quinquepunctatum.

Belemnites compressus, Stahl.
——— *irregularis*, Schloth.
Ammonites Aalensis, Zeiten.
——— *Comensis*, V. Buch.

At the base of bed (IX.) is a thin band of ferruginous sandy nodules, containing, in fact almost composed of, *Lingula Beanii*, and known as the "*Lingula* band." Below this band are some shales, more argillaceous and darker in colour than the above, containing also bands of impure ironstone with a blue oolitic grain. These shales are the bed (X.), and form the uppermost portion of the Upper Lias, being probably the representative of the Mitford Sands. They are sometimes called the "*A. striatulus* beds," from the occurrence of *A. striatulus* in them; they are also known as the "*A. Jurensis* shales."

Their thickness has been estimated at 70–80 feet; which seems a considerable exaggeration. A careful examination was made of these beds along the south-west side of the scar at Blea Wyke, and several bands of ferruginous nodules were seen, some almost composed of *Lingula Beanii*, not recorded before from beds so low, unless the description or measurements given by Tate and Blake are seriously inaccurate. From the fact of their being under water except at an unusually low spring tide, it is more probable that they have not been observed before. A very short distance from the scar to the north-west, patches of shale may be seen between the boulders which cover the foreshore, and *Leda ovum* may be easily found, so that the base of the shales containing the ferruginous nodules is probably not more than 30 feet below the first "*Lingula* band." The following is a list of fossils from these shales of the zone of *A. striatulus*:—

Rhynchonella Jurensis, Quenst.

Avicula substriata, Münst.
Lima Toarcensis, Deslong.
Ostrea subauricularis, D'Orb.
Pecten disciformis, Schüb.
**Leda inæquilatera.*
Trigonia literata, Y. and B.

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* Tate and Blake, Yorkshire Lias, p. 19.

Belemnites ventralis, Phill.
Ammonites Aalensis, Zeiten.
——— *insignis*, Schüb.
——— *Jurensis*, Zeiten.
——— *striatulus*, Sow.
——— *variabilis*, D'Orb.

From Blea Wyke these beds all thin away very rapidly, going north and west towards the Peak; and at the latter place they are less than half as thick as at Blea Wyke. Their course northwards is interrupted by the great Peak fault, and the Dogger is next seen in the Peak Alum Works, where it is a hard red highly ferruginous sandstone, about five feet thick, having a bluish interior when unweathered. At the base is a line of the characteristic pebbles, and small white specks occur throughout the whole; while the upper portion has almost a columnar appearance, from the vertical markings of *Equisetites* that occur in it. This ferruginous sandstone maintains much the same appearance throughout the district included in the Quarter Sheet 95 N.W.; weathering into rounded lumps or *doggers*, enclosed in a ferruginous crust. Its outcrop is easily traced proceeding westwards, as far as Howdale Beck, after which it becomes obscured by Boulder Clay. No fossils were observed in any of these exposures. In the small stream near Pretty House the typical ferruginous sandstone crops out, about 12 feet thick, but apparently unfossiliferous; and from this point it is not seen again till Ramsdale Beck is reached; but from the smallness of the exposure its thickness cannot be exactly ascertained. Its junction with the Lias is cut through at Row, and in the road above Park Hill; in both of which sections the Dogger is about 18 inches thick. It reaches the cliff at Hawsker Bottoms, and can be examined and measured on the pathway down the cliff, known as Sawdon's road or Jack-ass-road, where the following section may be seen:—

	Ft.	In.
Alternating sandstones and shales, three small coal seams near the base - - - - -	80	0
Typical dogger sandstone with pebbles, casts of *Belemnite* guards, and other shell fragments - -	5	0
Band of small nodules or pebbles - - -	0	2
Massive ferruginous concretionary nodules - -	1	0

The Dogger continues in the cliff, and at the northern edge of this district is only a few feet above high-water, the section here being nearly the same as that given above.

In Eskdale, between Ruswarp and Sleights, the Dogger is first seen in a small stream near the railway, and again in an old quarry a few yards off, where it is about eight feet thick; after which it is hidden by Boulder Clay and until Ugglebarnby in Iburndale is reached. In quarrying stone to build the church the upper part of the Dogger was exposed. A trial hole was driven into the bed, but it proved valueless as an iron ore.

At Little Beck Alum Works, and along the east side of the dale as far as Falling Force, very fine exposures occur; and here the sandstone is remarkably full of soft white specks, and contains sufficient carbonate of lime to effervesce with acid.

The number of fossils in it, especially in the lower part, is considerable; but as they are generally casts their specific identity is uncertain. *Lingula Beanii* is very abundant, as is also *Terebratula trilineata.* Two species of *Pecten,* two of *Trigonia,* a *Nerinæa,* occasional casts of an *Ammonite,* and fragments of *Belemnites* are among the more common fossils. The thickness of the Dogger at the Alum Works is about 15 feet.

On the west side of Iburndale an interesting section is seen in Wash Beck, the central portion of the bed being a coarse siliceous grit. The other exposures are at the Thornhill Alum Works, and the road-side above Sleights in Iburndale, and at the Alum Works in Eskdale. In the latter place the Dogger is about 12 feet thick, and has often been tried as an iron ore, but always without success.

The only section on the north side of the Esk is in the small stream that flows down from Aislaby past Woodlands, and is as follows:—

	Ft.	In.
Typical Dogger sandstone	3	0
Soft sandy shale	5	0
Whitish sandstone, fossiliferous in lower part	2	0
Total	10	0

The fossils are mostly casts, a species of costate *Trigonia* and *Pholadomya Sæmanni* being most abundant.

Lower Estuarine Series.—Above the Dogger at Blea Wyke[*] we have the following series of Estuarine or freshwater beds, capped by the thin marine bed, the "Eller Beck Bed."

	Ft.	In.
Shales, soft and light coloured, with a band of ferruginous nodules containing plant remains	20	0
Carbonaceous shale	1	0
Shale, rather sandy	20	0
Carbonaceous shale	2	0
Very hard sandstone	2	0
Shale, soft and soapy to the touch	8	0
Sandstone, somewhat flaggy	5	0
Shale	5	0
Sandstone	3	0
Dark shale	3	0
Shale with thin bands of very hard stone	30	0
Coal Seam	0	6
Underclay	2	0
Soft ferruginous sandstone, with vertical stems of plants, probably *Equisetites,* often 5 feet high	12	0
Shale, soft and light coloured	4	0
Coal Seam	0	2

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[*] This series was measured immediately over Blea Wyke with a thin rope, and found to be 180 feet in thickness. The difference of 20 feet is probably caused by the slope in the face of the cliff, which, however, is here very small.

	Ft.	In.
Sandstone, soft and rubbly	2	0
Coal Seam	0	3
Shale, dark coloured	6	0
Sandstone, coarse grained, ferruginous, and false bedded	24	0
Shale, dark coloured	10	0
Total	159	11

Dogger series, &c. Hard and ferruginous Sandstone.

At Hawsker and Whitby these beds have thinned away to slightly more than 100 feet.

An interesting feature in the Hawsker district is the occurrence of a thin seam of coal about three feet above the Dogger, its thickness being usually about four inches.

The following section at Nype Howe will show the position of the seam :—

	Ft.	In.
Sandstone	15	0
Dark carbonaceous shale	20	0
Coal Seam	0	4
Sandstone with roots (?) converted to jet	3	0

Dogger, with vertical *Equisetites* markings, &c.

This thin seam of coal can be seen at the top of the cliff immediately north of Normanby Stye Batts, and continues without interruption beyond High Whitby lighthouses. Other thin seams occasionally occur, not many feet above the Dogger, but as a rule they are continuous only for a short distance.

In the cliffs between Hawsker and Whitby we have remarkable variations in the series, as the entire cliff at Widdy Field consists of shale with a few thin beds of sandstone; while between Whitby and Saltwick the cliff consists chiefly of sandstone. As a rule sandstone predominates in these cliffs, the shale occurring only in thin bands; the alternations of the two, forming a series of waterfalls, as may be well seen in Ramsdale Beck, in the Robin Hood's Bay district, and elsewhere.

A typical section of the beds would be roughly as follows :—

	Ft.	In.
Shales, very variable, average	15	0
Sandstone, varies from 20 to 60 feet	60	0
Shale, increases as the sandstones diminish	15	0
Sandstone, in very irregular wedges	20	0
Shale, often carbonaceous	10	0
Total	120	0

Dogger at base.

This is approximately the section as seen along the steep eastern bank of Little Beck, just north of Falling Force; the Eller Beck Bed being at the top and the Dogger at the base of the series. The thick bed of sandstone is remarkably persistent, and is the source of a considerable part of the building stone of the district, the famous Aislaby quarries being in the lower part of it.

*Eller Beck Bed.**—This is so called from its fine development in the Eller Beck, near Goathland. It is first seen rising from the sea, at a point called Iron Scar, about a mile north of Cloughton Wyke, where the section is as follows :—

	Ft.	In.
Sandstone, close grained in upper part, and flaggy with streaks of dense ironstone near the base - -	12	0
Thin band of ironstone with *Nucula*, *Astarte minima*, in great numbers, also *Gervillia acuta*, *Arca* (sp.), *Corbula*, *Tancredia*, and *Littorina* - - -	0	3
Shales well bedded and ferruginous - - -	3	0
Thin band of ironstone, unfossiliferous - -	0	3
Shales, similar to above - - - -	1	6
Ironstone - - - - - -	0	3
Total - - -	17	3

The section remains practically the same over a considerable distance, the bed being easily traced at the top of the undercliff, between the Peak and Hayburn Wyke, up to the great Peak fault. It is not seen in the cliffs again till we reach Hawsker, where it first comes to the face of the cliff immediately on the north of Maw Wyke, from which point it continues to High Whitby, and after turning inland for a short distance once more reappears just north-west of Saltwick Nab. From this point it continues to the mouth of Whitby Harbour, where it is the capping rock of the East Cliff.

The only other exposure of this bed is in a little stream that flows into the Little Beck Alum Works. The section here is as follows :—

	Ft.	In.
Sandstone, flaggy and micaceous, splits to very thin laminæ in lower part - - - -	5	0
Shales, sandy in upper part, bluish grey below -	3	0
Sandstone, carbonaceous, and containing occasional ferruginous nodules composed of shells in the middle -	3	0
Ferruginous sandy shale - - -	0	5
Ironstone with *Pholadomya Sæmanni* - - -	0	5
Ferruginous shale - - - -	0	7
Ironstone casings with liquid mud inside - -	0	3
Total - -	12	8

The ironstone nodules in the middle of the second band of sandstone contain nearly the same fossils as the "*Pholadomya* ironstone" below. The chief are—a small *Gryphæa*, *Astarte minima*, *Cerithium*, *Cardium*, *Avicula*, *Gervillia acuta*, and a few other fossils.

A small distance above Falling Force, near Old May Becks, the hard sandstone at the top of this section may be seen dipping into the stream, but the shales and fossiliferous parts are completely covered by débris.

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* *Vide* Geol. Mag., Decade II., Vol. iv., p. 552 : 1877.

From the Eller Beck Bed to the Millepore Bed the Estuarine Series consists roughly of two parts, sandstone predominating in the upper portion, shale in the lower.

This feature is well shown in the section at Blea Wyke, which is as follows :—

	Ft.	In.
Massive false-bedded sandstone, very ferruginous -	60	0
Light sandy shale - - - -	8	0
Hard white stone - - - - -	0	9
Dark shale with underclay - - -	2	0
Shale with carbonaceous bands - - -	20	0
Hard white stone - - - -	1	0
Shale - - - - - -	9	0
Coal seam, very impure - - - -	0	4
Rubbly flaggy sandstone, rests on the *Eller Beck Bed* -	10	0
Total - -	111	1

In the great cliffs between Hayburn Wyke and the Peak this part of the series is usually covered by the débris from the upper cliff. There is, however, a very clear section at Hawsker, but the upper limit cannot be fixed, as the Millepore Bed appears to have died out.

The Millepore Bed.—The best section of this marine bed is on the shore just north of Cloughton Wyke, where it presents a somewhat conspicuous reef covered at high water. This reef consists of about 10 feet of massive sandstone, which is very ferruginous, and contains a considerable number of fossils in its upper part; but towards the base these die out, and the rock becomes a sandstone destitute of fossils. This reef, which represents the Millepore Bed to the south of Scarborough, is, however, not nearly so calcareous as at Cayton and Gristhorpe, and even what little calcareous matter remains seems confined to quite the upper part, and dies out gradually to the north, so that in the cliffs about Staintondale nothing remains but a few inches of rotten ferruginous beds with imperfect fossils. In the interior of the country we have been unable to make out the bed with certainty.

From the exposure at the north end of Cloughton Wyke the Millepore Bed rises in the cliff,* and may be traced as far as Hayburn Wyke, where it turns inland. At Hayburn, the ground being covered by Boulder Clay, and also probably much faulted, the outcrop becomes very uncertain, and can only be inferred from the distance of the beds above.

About half a mile south of Petard Point a little ferruginous sandstone, containing casts of fossils, crops out in the cliff edge; and from this point northwards it may be seen at intervals near the base of the upper cliff. About 500 yards south of Blea Wyke, where the word "Spring" is written on the six-inch map, is the following section :—

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* From the red ferruginous sandstone in these cliffs we obtained *Ceromya Bajociana*, *Modiola imbricata*, and a *Pinna*.

	Ft.	In.
Shaly sandstone, very ferruginous	5	0
Three bands of ironstone in very ferruginous sandy shale	3	0
Sandstone, calcareous at top and very ferruginous throughout, probably	6	0
Total	14	0

The lowest of the three bands of ironstone contains a considerable number of fossils. The chief are—

Modiola imbricata, Sow.
Trigonia recticosta, Lyc.
Unicardium ?
Arca.
Cucullæa.

The upper few inches of the sandstone are so calcareous as to pass almost into a ferruginous sandy limestone. Fragments of crinoids occur in some abundance in a crystalline condition, and give the rocks a semi-crystalline aspect. There are a few species of fossils in this bed, but they are difficult to extract.

A little further north, where a footpath leads up the cliff from "Fox Holes" towards Peak Hall, the following section may be seen :—

	Ft.	In.
Hard yellow sandstone	5	0
Soft yellow calcareous sandstone, with fossils	0	2
Hard ferruginous band, many small fossils	0	4
Flaggy sandstone, speckled white	1	6
Flaggy sandstone	3	0
Dogger band, speckled white	0	6
Soft white sandstone, seems to contain a few casts of fossils	2	0
Total	12	6

This bed caps the cliff at the gardens of Peak Hall; and from this point its outcrop takes a direction inland at right angles to the cliff, until meeting the Peak Fault, when it is thrown up to the top of High Moor over the Peak Alum Works. A thin bed of ferruginous sandstone, with a few indistinct casts of small fossils, may be seen in the gutter by the side of the high road from Staintondale to Bay Town; beyond this we have been unable to identify the Millepore Bed.

Middle Estuarine Series.—This is the principal coal-bearing horizon of the Lower Oolites; it consists in the main of shales, with three or four well-marked bands of sandstone, containing great abundance of plant remains. The sandstones frequently die out within short distances, but some of the beds seem more persistent than others.

There are one or two thin coal seams in this series, but they have never been much wrought in the district described by this Memoir. At Maybecks a drift has been put into the highest seam about 10 feet below the Grey Limestone Series; and a seam is said to have been worked near Cloughton Wyke, but this may have been simply a *soft jet* pit. In former times, this *soft jet* or

Oolite jet was very extensively worked, usually being obtained by drifting in at the outcrop of the rock in which it occurs; pits, however, were sunk where the jet occurred in sufficient quantity. The most extensive *soft-jet*[*] mining was formerly carried on at Gate Holm Wood and High Normanby in the Hawsker district, and on a smaller scale at Cloughton Wyke, &c.

Except at Hayburn, where they have been removed by denudation, these beds are well seen all along the cliffs from Cloughton to the Peak. North of the Peak, from the dying out of the Millepore Bed, this division of the Estuarine Series becomes amalgamated with those below, and their further outcrop has been described under that head.

The sandstone at the top of this series is very hard and siliceous; and in the neighbourhood of Harwood-dale, where it is quarried as a road stone, the workmen give it the name of "flint." At Cloughton this bed contains at its base a few small fossils, apparently some species of *Ostrea* or *Gryphæa*, accompanied by the species referred to in the foot note on page 42. These, and closely allied species, usually occur at the base and often at the top of the marine beds in the Lower Oolite, and seem to mark the gradual change from marine to freshwater conditions. In consequence of this it may appear doubtful whether the sandstone should not be included in the Grey Limestone Series; but as it forms a passage, it seems more convenient to separate it from the distinctly marine series above.

The following clear section of these beds may be seen at Cloughton Wyke:—

	Ft.	In.
Evenly-bedded massive sandstone, slightly calcareous, with a few small fossils at the base - -	13	0
Soft rubbly stone with a band of dark shale at top -	11	0
Hard dark shale - - - -	2	0
Soft shale, ferruginous in parts - - -	15	0
Hard sandstone - - - -	1	0
Soft sandy shale - - - - -	2	0
Thin band of wavy micaceous sandstone - -	0	10
Shale - - - - - - -	1	4
Sandstone with *Equisetites* at top - -	1	4
Shaly Coal - - - - - -	0	6
Dark sandy shale - - - - -	0	9
Sandstone with *Equisetites* - - -	9	0
Shaly sandstone with wavy lamination - -	3	6
Carbonaceous shale with irony doggers - -	1	0
Sandy shale with vertical *Equisetites* - - -	2	6
Grey soapy shale with plant remains - -	0	10
Dark carbonaceous shale - - -	0	6
Grey soapy shale with plant remains - -	4	6
Coaly Seam - - - - - -	0	2
Shale with thin hard sandy bands and soft jet - -	5	0
Sandstone well bedded, becomes shaly at base, also containing nodules in another place - -	10	0
Grey shale - - - - - -	1	3
Seam of Coal and shale - - - -	0	7

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[*] An inferior variety of Jet is now imported from Spain, which, from the cheap rate at which it can be obtained, has superseded the *soft* or *Oolite jet.*

	Ft.	In.
Dark grey shale, occasionally coaly and ferruginous	2	0
Shale with coaly streaks	0	6
Grey sandy shale	0	7
Sandstone with carbonaceous markings	2	3
Well laminated shaly sandstone and sandy shale with ferruginous streaks	2	6
False-bedded sandstone with irony partings, fossiliferous in places, containing lenticular patches of rocks similar to the Millepore Bed	7	9
Total	103	2

Another good section of these beds may be seen at Blea Wyke :—

	Ft.	In.
Dark shale, coaly at base	2	6
White rubbly false-bedded sandstone with shale partings	40	0
Hard white sandstone with *Equisetites*	3	0
White shale with carbonaceous band at top	20	0
Coal Seam	0	10
Shale	3	0
Sandstone, hard and white	3	0
Total	72	4

Millepore Bed at base.

This is probably an under-estimate of about 15 feet, too much having been allowed for the slight slope of the cliff. The bed of sandstone above is usually included in the Middle Estuarine Series; but here it is so unmistakably marine that we have included it in the Grey Limestone Series. If this bed of sandstone were added, the total of the Middle Estuarine Beds would be 99 ft. 6 ins., or nearly 100 ft.

In the cliffs at Hawsker there is no Millepore Bed, as observed above (p. 35), and therefore we cannot fix a base to the series; but the beds immediately under the Grey Limestone in this district consist principally of shales with thin sandstones, soft jet, and thin coal seams. This part of the Estuarine Series is scarcely ever well exposed inland.

Scarborough or Grey Limestone Series.—This, which is the most important marine series of the Lower Oolites, has a very regular outcrop throughout a large portion of the map. It consists in the main of a series of siliceous and calcareous bands with shaly partings, and usually towards the upper part a considerable thickness of shale.

One of the best sections of these beds is that exposed in the cliffs at Cloughton Wyke, where the following section was measured :—

Cliff Section, Hundale Point, Cloughton Wyke.

	Ft.	In.
Irregular bedded sandstone with carbonaceous matter at base.		
Ferruginous shale	6	0
Ferruginous bands with fossils in lower part	4	0

	Ft.	In.
Shale with great numbers of fossils: *Belemnites giganteus, Avicula Braamburiensis, Avicula inæquivalvis, Gervillia acuta, Pecten clathratus, Astarte minima, Modiola imbricata, Myacites Scarburgensis*	27	0
Reef of grey shaly limestone with *Avicula Braamburiensis, Ostrea flabelloides, Perna rugosa, Myacites calceiformis, Pentacrinus*, and *Serpula*	4	0
Second reef of shaly limestone	2	0
Shale with *Belemnites giganteus, Avicula Braamburiensis, Pecten lens, Pinna cuneata*	1	6
Third reef of shaly limestone	1	0
Shale with few fossils: *Avicula Münsteri, Cardium*	2	0
Fourth reef, hard limestone	1	0
Sandstone with fucoids: fossils in upper part	3	6
Hard siliceous sandstone forming a scar which runs out to sea	2	6
Shale with fossils	1	0
Ironstone	0	6
Siliceous sandstone with ripple marks in two bands	2	0
Shaly sandstone with wavy lamination	2	0
Hard shale	2	0
Coaly shale	0	4
Ironstone band	1	4
Hard fossiliferous grey shaly limestone: *Gervillia acuta* very abundant	4	0
Shale	2	0
Black shale	2	0
Total	71	2

Sandstone, forming Hundale Scar, 13 feet.

From Hundale Point the Grey Limestone Series may be seen in the upper part of the cliff, nearly as far as Hayburn Wyke, at which point it turns inland across Cloughton Moor until it is cut by the Peak Fault.

To the north of the great depression at Hayburn Wyke there is an outlying portion of this series, which is well seen in the Staintondale cliffs, and in the neighbourhood of Blea Wyke. In the latter place it appears to attain its greatest thickness, as will be seen from the following section, which was measured in the cliffs above the Point:—

Section at Blea Wyke.

	Ft.	In.
Flaggy sandstone with *Myacites* in great numbers along the lines of bedding: *Avicula Braamburiensis* and a small *Pecten* abundant in the lower part; *Pholadomya Sæmanni?* occasionally found	15	0
Sandy shales, rather harder on top, with small ironstone nodules containing *Avicula Braamburiensis*, becoming soft and calcareous in the middle, and harder and more calcareous towards the base; *Belemnites giganteus* occurs somewhat plentifully in this series	55	0
Calcareous sandstone which weathers into blocks with a rounded outline, the outer face often covered with stalactite: many small fossils	5	0
Band of flaggy limestone which weathers easily away: *Avicula Braamburiensis, Pecten lens*, and *Gervillia acuta* very abundant	2	0

	Ft.	In.
Hard calcareous shales with nodules of close-grained limestone almost composed of shells	10	0
Band of flaggy limestone having the appearance of hard calcareous mud	2	0
Thin flaggy sandstone with *Myacites* along the bedding planes, passing gradually to a sandy shale: casts of a small *Pecten* are very abundant near the base	15	0
Total	89	0

From the cliff section at Blea Wyke the outcrop of these beds again turns inland, and continues in a direction slightly north of west till it is cut by the Peak Fault a little east of Crag Hall. By this fault the beds are thrown up to the west, and their outcrop is very obscure for some distance. At Pye Rigg shales with *Avicula Braamburiensis* are seen, which can be traced with more or less certainty along the sides of Helwath Beck to its junction with the Jugger Howes Beck below Dry Heads, where there is a splendid section of these measures.

Section in Bloody Beck, Harwood-dale.

	Ft.	In.
Massive sandstone.		
Hard ferruginous sandy shale	2	3
Hard ironstone band with *Avicula Braamburiensis*	0	3
Quartzose gritty band	0	2
Grey sandy shale, getting harder at base	1	6
Calcareous band full of *Avicula Braamburiensis*	0	4
Cherty band	1	0
Shale	0	7
Hard calcareous band	1	10
Dark argillaceous shale with large *Ostrea*	1	2
Quartzose gritty band crowded with *Avicula Braamburiensis*, becoming sandy at bottom	2	2
Ironstone band	0	6
Shale with nodules and great numbers of species	15	0
Hard calcareous band with fossils	3	6
Hard limestone with well-marked joints containing *Gervillia acuta*	1	0
Shaly limestone more calcareous in parts	5	0
Blue flinty bed	0	7
Flaggy ripple-marked cherty bed	0	5
Main flinty bed	1	4
Cherty sandstone with fossils	8	0
Total	46	7

Across Howedale Moor the outcrop of these beds can be well traced by thin flaggy bands of sandstone containing casts of a small *Gryphæa*;[*] and near Cook House shales with *Avicula Braamburiensis* are seen. The thin flaggy sandstones seem to be very persistent at the top of the Grey Limestone Series, and continue north and west at least as far as Kirk Moor Gate on

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[*] Figured by Prof. Phillips, Geology of the Yorkshire Coast, 3rd Ed., Plate IX., Fig. 26.

Fylingdales Moor, where in the beck to the north-west side of the Scarborough road the following section may be seen:—

	Ft.	In.
Thin flaggy sandstone (capped with gravel). In one part of the stream it is slightly contorted - - -	20	0
Dark coloured sandy ironstone-nodules with few fossils	0	4
Dark micaceous shaly sandstone: a few plant remains -	0	10
Thin ironstone and sandstone with a few fossils -	0	8
Band of ironstone, almost composed, in parts, of fossils: *Avicula Braamburiensis, Trigonia recticosta*, a small *Chemnitzia*, &c. - - - - -	0	6
Thin sandstone and shale with a few small fossils -	2	0
Ferruginous shaly concretions with fossils - -	0	7
Dark sandy shale with very small quartz pebbles -	0	5
Ferruginous-sandy nodules with a few small fossils -	0	5
Dark shale with many casts of fossils - -	0	4
Calcareous ironstone, very hard: *Avicula Braamburiensis* very abundant - - - - -	0	8
Shale, darker and less sandy, with one thin band of ironstone: *Avicula Braamburiensis* scattered throughout -	4	0

The hard calcareous beds below are covered by drift and débris, and therefore are not well seen in this section.

There is a repetition of part of the above section (in a little stream) about 200 yards to the north-east; and still further to the north-east, on the side of a small gully over Stevenson's Piece waterfall, there is a slight exposure of the upper part of the shales, while fragments of the calcareous beds have weathered out. From this point northwards the outcrop is rather uncertain, owing to a thin coating of drift which covers the moor, and also to the fact that the hard quartzose grit, which is the usual representative of the Moor Grit, seems to be absent, and therefore there is no good feature to form a guide.

There is no positive evidence of this series across Fylingdales Moor; but that its outcrop has been proved in former times is probable from the name "Graystone" given to these hills, a name used in several places where beds of grey flaggy limestone have been dug out for liming the land.

The sandstone quarried at Soulsgrave is, from its lithological character, probably the Moor Grit, from which we can infer the outcrop of the bed below; while in the fields on the northern end of Ugglebarnby Moor small fragments of ironstone, with *Avicula Braamburiensis*, have weathered out of the shale.

In making a shallow well at the new lodge at Newton House the lowest bands of shaly limestone were passed through, and the sinking was continued below to a seam of coal which was found at a depth of about 15 feet.

At New May Beck Plantation a small quarry has been opened in the hard calcareous bands. The upper of these is about 4 feet thick, and of a bright blue colour in the interior; but the outer part soon loses its lime, and becomes a soft ferruginous sandstone, with a considerable number of casts of small fossils. The rock seems to decompose too readily to make a durable road metal. The flaggy bed below is more sandy than at Peak; but it still contains much lime, and the usual fossils are very abundant in it.

From this point till the beds sink beneath Blea Hill Beck the outcrop is very clear, and the following section may be seen in descending order:—

	Ft.	In.
Shales with small doggers of ironstone and fossils -	15	0
Band of hard blue calcareous and ferruginous sandstone	0	8
Sandy shale, slightly calcareous - - -	4	0
Calcareous sandstone, with a band of grit in the middle, almost composed of casts of *Avicula Braamburiensis* -	2	6
Calcareous sandy shale or impure flaggy limestone -	3	0
Hard limestone band full of shells in a crystalline condition - - - - - -	0	10
Hard calcareous shale - - - - -	2	0
Flaggy sandy calcareous bed, harder in the centre -	3	0
Blue calcareous sandy band - - - -	0	6
Calcareous sandstone, shaly in lower part, containing a few plant remains and small fossils - - -	7	0

The two calcareous sandy beds make fairly good road metal, and the 10-inch limestone band will probably do the same. This latter is the only bed in the whole series that can fairly be called a limestone, the best of the other bands upon analysis yielding, according to information, only 34 per cent. of carbonate of lime.

The top of the series is not exposed in the bank, but there is probably not more than five feet of shale hidden by the débris of the Moor Grit; and in the bed of the stream further south there is a flaggy sandstone with casts of *Myacites* in considerable numbers at the top of the shales. About 10 feet below the base of the series is a coal seam, said to average 11 inches thick; its outcrop can be seen, and there is a drift into it exactly under the spot where the above section was measured.

There are several other fine exposures of these beds in this neighbourhood, the western branch of the May Beck stream presenting a section several hundred yards long. The principal fossils here are *Avicula Braamburiensis* in great profusion, *Gervillia acuta, Pecten lens, Nucula minima,* a small *Trigonia, Ostrea,* apparently two species, and many *Belemnites;* but there is a remarkable paucity of species, except in the hard limestone band, from which, however, it is difficult to extract them.

For a short distance along the left bank of the stream the outcrop is marked by small masses of calcareous tufa, in which are some fine impressions of leaves of recent plants; but there is no absolute exposure till reaching Parsley Beck, where a good section of the lower hard calcareous beds may be seen. From this point the outcrop on Sleights Moor can only be fixed by the Moor Grit above, and the small fragments of ferruginous sandstone or ironstone with *Avicula Braamburiensis* that have been weathered out of the shales.

There is a small exposure of the lower hard beds of sandy impure limestone in Little Beck, not far from Goathland; but the rest of the series is completely obscured by fallen blocks of sandstone, &c. in the bed of the stream. At the base of the Moor Grit is the flaggy sandstone, containing casts of *Myacites* in great numbers.[*] In Brocka Beck a nearly complete section can be seen, much resembling that at May Beck; but the beds as a whole are less calcareous, and much of the argillaceous matter is replaced by silica, so that the beds in the lower part of the series have become considerably harder, and not nearly so fossiliferous as they were to the east.

In Eller Beck, near where the Whitby road crosses that stream, there is also a good section of the upper part of these beds, which seem to be rather more ferruginous at this spot. A short time since, a day hole was put in close to the bridge, with the hope of working them for iron ore, but apparently without success. To the west of this the beds are seen rising in the railway cutting, and they then strike across the moor towards Killing Pits in the next map.

In the northern part of this map, and extending into 104 S.E., is a large outlier of the Grey Limstone Series, capped by the shales and sandstones of the Upper Estuarine Series, the whole being cut in two nearly equal parts by the Whitby Fault.

The most southerly section near the coast is at a waterfall at Gate Holm Wood, near Hawsker Bottoms, about 500 yards inland from Maw Wyke; it is as follows, in descending order:—

	Ft.	In.
Dark grey shale	2	6
Band of ironstone doggers with fossils	0	6
Dark shales	2	6
Ironstone band, with *Avicula Braamburiensis, Pecten lens, Gervillia acuta, Cucullæa cancellata, Astarte minima,* a large *Trigonia*, and several other fossils	0	10
Calcareous sandstone in cubical blocks containing many small fossils	5	0
Flaggy impure limestone containing a few species in great abundance	3	0
Sandy calcareous shales	5	0
Hard dark calcareous shale with nodules of limestone almost composed of shells in a semi-crystalline condition	3	0
Impure flaggy limestone very fossiliferous	3	0
Dark shale with a few fossils	2	0
Total	27	4

The last band of flaggy limestone makes a fall of about 15 feet, the beds beneath consisting of dark shales and thin sandstones. This is an exceedingly convenient section to examine, as the limestone beds were formerly quarried and burnt for lime, the flaggy bands being also used as paving for footway. Many blocks with *Pecten lens, Avicula Braamburiensis*, &c. may now be seen in the paved footway from Whitby to Robin Hood's Bay.

The upper flaggy limestone band continues in the bed of the stream for some distance to the south, while the shale may be occasionally seen in the banks of the stream; and proceeding northwards the hard calcareous beds crop out in several places along the sides of the next small stream near Nype Howe.

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[*] There can be little doubt that this shell is a *Myacites*, and not a freshwater shell, for it is identical in size and shape with the shells occurring in a similar position at the Peak, where they are accompanied by several marine species.

From this point the outcrop of the Grey Limestone passes into the next map; and then, skirting round to the south of Whitby, enters this area again near Cock Mill. A little south-west of the mill a series of very interesting sections may be seen in Shawm Rigg Beck, and its tributaries towards Sneaton. Although the entire series may be seen three or four times over, the vegetation is too great to permit of a carefully measured section. The following, however, is probably near the truth:—

	Ft.	In.
Light-coloured sandy shales with thin bands of sandstone containing a few fossils: at the base is a row of ironstone doggers with *Avicula Braamburiensis* in great abundance - - - - - -	10	0
Calcareous sandstone, very hard and difficult to break, having a bright bluish grey colour on a newly fractured surface. The upper part of this bed is sometimes covered with fragments of crinoidal stems - -	4	0
Flaggy limestone band, hard and sandy: *Gervillia acuta* is very abundant, also a finely striated small *Pecten* -	1	6
Calcareous shale; exact thickness doubtful - -	5	0
Very hard calcareous bed with a conchoidal fracture towards the base - - - - -	2	0

The outcrop to the south of this has to be inferred, as the only evidence of its presence are the flagstone quarries in the Moor Grit in and around Sneaton. In the Harwood-dale valley near Burgate, there is an inlier of these beds, of which a few feet are exposed in Grange Wood; but the general outcrop is very obscure. Again in the small valley below Ripleys these beds must also crop out, but we were unable to make out the section, and the lines have been put in by aid of the Moor Grit, both here and to the south of Cloughton.

The Upper Estuarine Series.—These beds occupy nearly the whole of the moorlands in the centre of the map. They have a thickness of over 200 feet, and consist principally of shale, with a few irregular bands of sandstone of little commercial importance, and one or more beds of granular iron ore. These rest on a massive bed of sandstone, which, on account of its development in the interior, has been called the "Moor Grit." This latter frequently makes an excellent building stone, and is quarried at Cloughton, while at Sneaton it supplies the district with flagstones. The outcrop of these beds covers a larger area of surface in this district than any other division of the strata that we have to describe.

Commencing on the coast north of Scarborough, these shales occupy a great belt of county right across the central portion of the map, forming nearly the whole of the great spreading moors of Harwood-dale, Fylingdales, and Goathland, and extending up the valley of the Derwent, and its tributaries, into Troutsdale and Crosscliff.

The Moor Grit, which is well seen in the cliffs about Cloughton and Staintondale, forms a somewhat conspicuous feature along the amphitheatre of hills above Robin Hood's Bay, to the south of Sneaton, and generally across the moorlands. As we mentioned above, it is frequently the only guide in tracing the softer beds of the Grey Limestone Series below. It also crops out in Eller Beck, in the bed of the Derwent near its source, and in Harwood-dale.

The Cornbrash.—This, which is the highest bed of the Lower Oolites, is only a few feet in thickness, and therefore never makes a large spread; but it is found in the steep bank at the base of the Middle Oolites along the southern portion of the map, where it has a very extended outcrop.

In the banks of the stream below Low Langdale End the Cornbrash is well exposed, and the following section was there measured:—

	Ft.	In.
Hard ferruginous limestone with fossils - -	2	0
Shaly sandstone - - - -	1	0
Sandstone with root-like markings - - -	4	0

Further north the fossiliferous portion appears to be rather thicker; and in the upper part of Langdale, where this bed is seen in several places, the measurements are:—

	Ft.	In.
Hard limestone with *Ostrea Marshii* - - -	3	0
Shaly bed - - - - -	1	0
Sandstone with markings - - - -	2	6

In Newton Dale, just beyond the western edge of the map, the thickness of this rock has very much increased, and it attains greater importance than in any other part of Yorkshire. It is well seen in the natural precipices along this valley, having a thickness of rather more than 10 feet, in three or four distinct beds.

The outcrop of the Cornbrash continues from the south of Hackness along the sides of the Derwent valley, and the branch streams coming down from Troutsdale, Bickley, and Crosscliff. From thence, skirting the sides of the beautiful Langdale gorge, one part turns to the east, and, striking along the hillside above Harwood-dale and Scalby, completes the circuit of the Hackness Hill; the other part, turning west, follows the right bank of the Derwent to High Woof How, near the source of that river, where it attains an elevation of over 900 feet, and thence falls gradually towards Fen Steps into Newton Dale.

Besides the large outlying portion of this rock at Hackness several smaller outliers occur at Throxenby, on Langdale Moor, Harwood-dale Moor, and at Blea Hill.

MIDDLE OOLITES.

The Middle Oolites, although merely a continuation of the beds described in the Explanation of the Map to the south,* are particularly well developed in this Quarter Sheet; and there are several important changes which it will be necessary to notice.

The Kellaways Rock.—This, the lowest bed of the Middle Oolites, which was gradually becoming thicker towards the north, has in this map attained considerable importance. This is chiefly owing to the base of the Oxford Clay above having become more sandy and passing into rock, the combined thickness of the two remaining about the same. Along the northern part of the outcrop of this rock the thickening of the upper portion of the sandstone is very remarkable; for on Blakey Moor, and near the higher part of Langdale, the upper part forms a distinct feature above the general spread of the rock on Lockton, Allerston, and Wykeham High Moors. This upper feature appears to be separated from the main mass of rock below by a thin band of clay, which seems to die out towards the southern edge of the map; but the lines are very obscure, and it is probable that there is a gradual passage from one into the other, as is the case in all the lower subdivisions of the Middle Oolites.

The central portion of the rock is a massive sandstone, graduating into shale both towards the top and towards the base. In the west of the map this more massive portion forms a large spread of moorland, which has very much the character of a Millstone Grit moor, especially at Grey Stones and Thompson's Rigg, north and south of Blakey.

The Kellaways Rock has been quarried at Hackness for a great number of years, and is a most excellent building stone if the blocks are carefully selected. Professor Phillips says, "Its durability is evinced by the condition of the stone in the ancient church at Hackness, which was probably built about the end of the thirteenth century; and its good effect in architecture may be seen to great advantage in the new church and new museum at Scarborough, and especially in the museum of the Yorkshire Philosophical Society [at York], in the construction of which blocks of great magnitude have been employed."

The outcrop of this rock usually forms a well-marked feature about half-way down the great escarpment formed by the Lower Calcareous Grit; but in the west of the map it forms a greater spread, and stretches away to the north as far as Tom Cross Rigg and High Woof How, where it attains its greatest elevation,—950 feet above the sea.

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* The Geology of the Oolitic and Cretaceous Rocks south of Scarborough (Geological Survey Memoir), pp. 12–22, 1879.

There is an inlying portion of this rock in the Hole of Horcum, and several outliers at Scarborough, Throxenby, Hackness, Langdale Moor, Harwood-dale Moor, and Blea Hill. At Hackness the Kellaways Rock, although covered in great measure by superior beds, is found in the bottoms of the valleys which intersect the hill.

The Oxford Clay.—The Oxford Clay, which, as we have just noticed, is so intimately connected with the Kellaways Rock that it is difficult to say where the base of it should be placed, is throughout its whole thickness rather a sandy shale than a true clay.

It occupies a narrow band below the escarpment of the Calcareous Grit, and its outcrop is usually well shown by being that portion of the steep slope which is brought into cultivation. The Calcareous Grit above is either moorland or plantation, while the Kellaways Rock below usually flattens out into a terrace of greater or lesser extent.

This clay or shale crops out at the base of the Calcareous Grit escarpment along the banks of the Derwent and its tributaries, between Hackness and Saltersgate, and along the sides of the outliers of Hackness Hill, Langdale Rigg, and Blakey Topping. There are also inlying portions, of small extent, in Staindale and the Hole of Horcum.

The junction of the upper portion of this clay with the base of the Calcareous Grit is so gradual that no exact line can be drawn. The most marked horizon, and perhaps the best on account of the change in soil and the purposes to which the land can be applied, is that where the numerous springs burst forth, and which is also shown by the general wetness of the land below. The Calcareous Grit above this point is also very shaly, and does not become a true sandstone rock for at least another 50 feet or so. These junction-beds are generally well seen in the steep "griffs" which terminate the valleys in this district, and which are kept clear of vegetation by their rapid denudation.

The Oxford Clay was formerly, at Coomboots, used for making bricks and tiles; but it was found to be too sandy to be of much value, and it has since been abandoned in favour of the more argillaceous clays of the Cornbrash which crop out a little lower down the hill.

The Lower Calcareous Grit.—This rock, which forms the most striking physical features in the district, crops out in the southern portion of the map in a series of bold escarpments; generally facing the north, but also flanking the course of the Derwent and its tributaries in the neighbourhood of Hackness, Troutsdale, and Langdale End; and, stretching thence away to the west in the magnificent sweep of Crosscliff, attains its greatest elevation—950 feet—at Saltersgate.

Besides the main mass of the rock there are several remarkable outliers. Of these the largest is that at Hackness, which, although forming a compact mass with an unbroken scarp on the east, north, and west, is deeply cut into in its central portion by the several branching valleys which drain into the Derwent at Hackness.

Another very remarkable outlier is that known as Langdale Rigg. This ridge, although nearly two miles in length, is often not more than 50 yards broad at the top; and, rising to a height of 800 feet at its northern extremity, it has a very peculiar aspect when viewed from the north side of Robin Hood's Bay.

There are also the curious conical hills at Low Langdale End, and that of Blakey Topping, the summits of which are formed of this rock. A curious feature of this formation are the numerous spurs or nabs into which it has been denuded by the springs and small streams issuing from the Oxford Clay below. These nabs, which have a very striking appearance around Hackness and towards Troutsdale, have a marked resemblance to natural fortresses; and the remains of dikes and other ancient works which are scattered over their summits would seem to indicate that they were an important stronghold in former times.

The lithological character of the rock is similar to that described in the map to the south, being a massive yellow calcareous sandstone in its upper part, graduating into a sandy shale towards its base.

The Lower Calcareous Grit in this map attains a very great thickness; including the shaly beds at the base, it cannot be much less than 150 feet.

The Greystone.—This bed, which to the south was described under the name "Greystone," is better known about Hackness by that of "Wallstone." Although only about 20 or 30 feet thick, it is a well-marked bed in this district, and represents the passage from the Calcareous Grit below to the Coralline Oolite above, but is very different lithologically from either of them.

On the Hackness outlier it is a hard "glance" limestone, rather ferruginous in places and very fossiliferous, and capable of being split into slabs for building walls and other purposes, for which it is largely used. The lower part of the rock graduates into soft sands, and these again into the more solid sandstone of the Lower Calcareous Grit below.

Further to the west, beyond Bickley, this rock changes very much in character. Becoming much more gritty, and losing the calcareous aspect almost entirely, it passes into a true grit, with here and there a few lenticular aggregations of fossils and calcareous bands. It is this rock which forms those remarkable blocks known as Bride Stones; which, standing up on the bleak surface of the moor above Staindale in a most peculiar manner, have a very weird appearance. Besides several masses which join on to the side of the hill, and have more the appearance of ordinary crags, there are about 10 or 12 of these detached blocks, one of which measures as much as 80 feet in circumference and is 16 feet high. About half a mile further west this rock has the appearance of being run together and cemented by silica, and was found to be so hard as to require blasting. It is evidently this siliceous nature which has enabled the Bride Stones to stand out and resist the effects of the weather.

The Coralline Oolite.[*]—The Coralline Oolite, although capable of division into at least five separate horizons, is, on account of the extreme thinness of some of the beds, best described as one formation.

The complete series of these beds, having a total thickness of about 100 feet, is only represented at one place in the map, and even there only over a very small area. On the hill between Silpho and Hackness the whole of these subdivisions may be seen, forming as it were a hump of a more rounded outline overlooking flatter beds below.

Resting on the Greystone just described there may usually be observed a peculiar rubbly bed, which, although only a few feet thick, is of some importance. This bed, which is called by the workmen "Cold Head," is an impure siliceous limestone abounding with corals of the genus *Thamnastræa* and *Isastræa*. In fact it is a regular coral bed, similar to that described in the map to the south, but occupying a lower horizon, and containing a different fauna. It is quarried at several places for mending the roads, and being very hard is well suited for the purpose. Wherever this bed covers the surface for any distance it forms very good land, and the sweetest pastures of the district occur on it.

This Coral Bed is best seen at Suffield, Silpho, and Broxa, but there are indications of its extending as far as Bickley.

The Coral Bed is succeeded by a considerable thickness of oolitic limestone, which is separated into two portions by an intervening bed of sandy strata.

The lower of these limestones occurs at Silpho, Suffield, and on the moors to the west. It is of a good thickness in the neighbourhood of Hackness, but near Bickley it becomes very thin, although it thickens again further to the west near Lockton.

This limestone is characterized by the paucity of its fossils. It contains however the usual forms common to the lower portion of the Coralline Oolite, such as *Gervillia aviculoides*, *Ostrea flabelloides*, *Gryphæa mima*, &c.

The intervening bed, which represents the Middle Calcareous Grit of the map to the south, is a soft sandstone, containing *Modiola bipartita*, *Pecten articulatus*, and *Terebratula intermedia?* It is obscurely seen on the hill above Hackness vicarage; but it spreads out around the village of Silpho, forming a red clayey soil, and here it has been proved in numerous excavations.

The Upper Limestone occurs only on the hill south of Silpho, where it has been quarried at one or two places. It consists of several beds of massive oolitic limestone, much more fossiliferous than that below, and containing the following fossils in considerable abundance :—

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[*] There is an admirable account of these beds by Blake and Hudleston, Quart. Journ. Geol. Soc., vol. xxxiii. p. 329.

Thecosmilia annularis, Flemg.

Cidaris florigemma, Phill.
Cidaris Smithii, Wright.
Serpula.

Gryphæa mima, Phill.
Ostrea gregaria, Sow.
Astarte ovalis, Sow.
Myacites.

Chemnitzia Heddingtonensis, Sow.
Nerinæa.
Phasianella striata, Sow.

Above the limestone occurs a second coral bed; and although the junction is not well seen at Hackness, it is evident that it must lie above that just described. This bed is mainly composed of white crystalline limestone with *Thamnastræa concinna*, and is very similar to the Coral Rag mentioned in the map to the south. It stands up, in the fields on Loffeyhead Heights, in irregular bosses, which show the borings of *Lithodomi.*

Above the upper beds of limestone and coral rag on the west side of Loffeyhead is another thin bed of sandstone. Although not absolutely seen in section, it is sufficiently proved by the fragments in the fields, which contain fossils common to the Upper Calcareous Grit of Pickering and Kirkby Moorside.

The unique section which has been preserved on the outlier just north of Hackness represents no less than seven sub-divisions above the Lower Calcareous Grit. Of these the two uppermost have not been observed elsewhere in this district, the nearest exposure of the Coral Rag, at Ayton, being distant about four miles; while there is no outcrop of the Upper Calcareous Grit nearer than Pickering, at a distance of nine miles.

The following generalized section may help to give some idea of the character of these beds at Hackness, with their estimated thickness :—

	Ft.	In.
Soft reddish sandstone, not seen in section, about	10	0
Coral rag with *Thamnastræa concinna* and borings of *Lithodomi.* Massive oolitic limestone in several beds, very fossiliferous, with *Astarte ovalis*, *Chemnitzia Heddingtonensis*, *Nerinæa*, &c., in the upper part; and near the centre a very shelly bed, with *Thecosmilia annularis*, *Cidaris florigemma*, *Cidaris Smithii*, *Phasianella striata*, *&c.*	40	0
Soft sandy beds with *Modiola bipartita*, *Pecten articulatus*, and *Terebratula intermedia ?*	20	0
Massive oolitic limestone, poor in fossils, with *Gervillia aviculoides*, *Ostrea flabelloides*, *Gryphæa mima*	30	0
Cherty ragged beds, mainly composed of corals, *Isastræa*, &c.	6	0
Hard siliceous and ferruginous flaggy limestone, with *Gervillia aviculoides*, *Exogyra nana*, &c. &c.	25	0
Sandy beds of the Lower Calcareous Grit.		

CHAPTER IV.

IGNEOUS ROCKS.

The only igneous rock here to be described is that of the well-known basaltic "Whinstone Dyke" known as the Cleveland Dyke; which, after traversing the Oolitic Moorlands on the west, enters the map about three miles S.S.W. of Sleights.

The Whin Dyke crops out in a nearly straight line, running E.S.E. across Sleights Moor and Sneaton High Moor, where it forms the backbone or ridge of the long stretch of moorland, and where it has been extensively quarried. Its position may be well fixed by the line of "Howes" or tumuli upon it. It here comes to the surface through the Upper Estuarine Shales, which, for a distance of about 2 feet, it has baked to a hard white coarse porcelain, locally known as "China Metal." The breadth at the western edge of the map is about 28 feet, and by the time it has reached Blea Hill Rigg it cannot be more than 20 feet. Here the dyke may be a line of small fault; but this appearance is probably due simply to the Kellaways Rock slipping over the shales of the Cornbrash. The long heather, and the absence of blocks, make it uncertain if the Whin has come through the Kellaways Rock; but it seems probable that it has. It certainly cuts the Cornbrash on the east side of the hill; from which it only continues to be seen at the surface for a few hundred yards further E.S.E. Beyond this it is never seen again at the surface.

Throughout this district the Whinstone is a bright-blue basalt, of a lighter colour and finer texture than further to the N.W. It contains small crystals of glassy felspar; cavities are very rare, the few that exist being usually filled with Mesotype. The stone has a conchoidal fracture, and makes a high class of small road metal; but in this district it is not used for paving. At the surface the basalt has weathered into rounded blocks, generally small, enclosed in a ferruginous casing; but at some depth down it occurs in large blocks, rather angular in shape. The sides split up into thin plates of an inch or two in thickness, or more often into small prismatic pieces a few inches square; these are of a very fine close-grained texture; the centre of the dyke being usually rather coarser. The Dyke has a considerable hade, so that in crossing a valley its outcrop forms a slight curve, the apex pointing to the N.N.E.

CHAPTER V.

SUPERFICIAL DEPOSITS.

GLACIAL BEDS.

Boulder Clay and Gravel.—The Boulder Clay which occurs in this map is a portion of that great sheet which extends along the coast from Flamborough northwards. It maintains in this district its usual character of a stiff blue clay, with rounded and sub-angular pebbles and boulders, intercalated here and there with seams of sand and gravel, the striations on the harder kinds of stones having been preserved. The boulders have been derived principally from the Oolites and Lias; although blocks of Carboniferous Limestone, Granite, and other rocks foreign to the district are not wanting.

The drift on the northern side of Scarborough contains much more gravel than that to the south; and in the cliffs east of Burniston, where these gravels are well exposed, there are 140 feet of coarse but well stratified gravel and sand, with little or no clay. This is distinctly seen in several places, more particularly near Scalby Lodge and Burniston Fields, to fill up the hollows of old valleys. This drift, which entirely covers all the low ground about Scalby and Burniston, stretches up the valley at the foot of the Hackness Hill towards Harwood-dale, where it finally terminates in several detached mounds of gravel near Castlebeck Farm and Keasbeck Hill.

The two valleys on either side of Brown Rigg, which come down to Hayburn Wyke, have also been filled in with Boulder Clay and Gravel, which much obscures the rocks below. Probably these deposits have to a certain extent altered the courses of the streams, the present mouth being apparently 50 yards south of its old position. The thickness of drift in this valley must be considerable, as the present streams, although cut to a depth of nearly 100 feet, have failed to penetrate it in many places.

The high ground around the Peak is now almost free from drift, only very small patches being observed on the top of the cliff south of Peak Hall. But that this country was once covered by drift is quite clear from the great number of pebbles of foreign rocks, principally white quartz, which can be found even at the greatest altitudes; as, for example, on High Moor, over the Peak Alum Works, at a height of 850 feet above sea-level. The high moorland south and west of Robin Hood's Bay is free from drift, a fact which has hitherto prevented its reclamation, as the glacial beds form a far better soil than the barren Oolites.

Along the flanks of the hills encircling the Bay the drift has in most cases been washed off the upper part of the Upper Lias, wherever the shales of that formation form a high steep bank. This is very well seen all along the south and south-east escarpment of the Lias, where the face of the hill is free from drift as far down as the Jet Rock. The central part of the Bay is occupied by a thick mass of glacial deposits, which in the more easterly districts (as in a semi-circle round Bay Town and Fyling Thorpe) is divisible into three well-marked portions.

The *Lower Boulder Clay* is usually seen below the "Middle Sands," when the latter are present. It consists of a dark purple-coloured clay, very heavy, and containing many large boulders, the greatest number being of Shap granite, Whin stone, Carboniferous and Magnesian Limestone.

Middle Sands.—This, the second division of the Glacial beds, consists of sand and gravel; usually occurring in the following order, in the cliffs of Robin Hood's Bay:—

(I.) Fine sand, false-bedded, and containing fragments of coal. This bed passes rapidly to—
(II.) Coarse ferruginous gravel, largely composed of *Gryphæa incurva* and other broken fossils, chiefly Lower Lias species, large lumps of shale, especially of the Jet Rock, with pebbles of quartz and other rocks of foreign origin.
(III.) Fine sand, very similar to No. (I.)

These beds may be well seen in the cliffs in the middle of the Bay, and many fragments of *Tellina Balthica* can be found at the junction of (I.) and (II.)

There are a few other exposures of this sandy series. The chief are—at Spring Hill, near the Flask Inn; in the bank of the small stream near Brock Hall; and in the new cutting for the road to Ramsdale Mill. These sandy beds are the source of most of the water in Fyling Thorpe, where they are covered by a few feet of clay. Their thickness here has been proved to be more than 30 feet.

At Kirk Moor Gate, on the road from Whitby to Scarborough, there is an extensive deposit of gravel and sand, which appears to be of this age. Wind Hill forms part of it, and consists of soft sand; but the rest seems to be a fine, rather sharp, sand and gravel, mixed together, and can be seen resting immediately on the Moor Grit beneath.

The *Upper Boulder Clay* is of a light-red colour, with a small admixture of foreign pebbles, rarely of large size. This clay is not very heavy, and contains a considerable admixture of sand, often in thin bands; in consequence of this it is sometimes used for brickmaking.

POST GLACIAL BEDS.

Peat.—Although the growth of peat on the moors takes place wherever there is a "slack place," or where the drainage is in any way arrested, still there are comparatively few places where it covers any considerable area. The principal deposits are on Harwood-dale Moor, near the Falcon Inn; May Moss, on Allerston High Moor; and Fen Bogs, over which the Whitby Railway is carried. These latter are both on the line of watershed, and consequently the waters from them flow both north into the Esk and south to the Derwent. Besides these there are smaller patches near the Saltersgate Inn, above Staindale, on Suffield Moor, and generally in the higher parts of most of the moorland streams.

This peat is at present dug in only three places,—at Fen Bogs, on Allerston High Moor, and at the Falcon; the inhabitants preferring the turf or roots of the heather to the genuine black peat for purposes of fuel.

Alluvium.—Alluvial deposits, forming flats slightly raised above the level of the streams, occur along the valleys of the Esk and Derwent; and there is also a small patch of alluvial clay just south of Burniston, filling an old hollow in the Boulder Clay.

CHAPTER VI.

PHYSICAL STRUCTURE.

The geological formations which come to the surface in this map may be said to divide the country into three separate areas, having somewhat different characteristics, but corresponding more or less to their respective geological divisions.

In the south of the map are the great flat-topped hills of the Middle Oolite, forming the north-east corner of the tabular range which extends from Hambleton to Scarborough. These form a bold escarpment to the north, which extends in a more or less unbroken line from Saltersgate to Scalby. At Hackness the Derwent and its tributaries break through this range, and, by forming the hills into numerous projecting spurs, cause much diversity in the landscape, giving rise to some of the finest scenery in the district.

At the base of this great escarpment are the shales and sandstones of the Lower Oolites, spreading out to the north in a vast tract of wild moorland, which at Lilla Howe attains a height of 978 feet above the sea. These rocks occupy by far the largest part of the map, covering nearly all the high ground with the exception of that mentioned above. They form also the moors near Saltersgate, known as Lockton, Allerston, and Wykeham High Moors, where the Kellaways Rock runs out from beneath the general mass of Middle Oolite, and forms a considerable spread. The Lower Oolites also constitute the entire thickness of the cliffs from Blea Wyke to Scarborough, with the exception of those which are covered by Boulder Clay.

The third and remaining area comprises the deep valleys in the north of the map, formed by the Esk and its tributaries; it also includes the hollow of Robin Hood's Bay. When these dales are cut to a great depth in the Lias they are beautifully symmetrical; as is well shown on the south side of Robin Hood's Bay, where the great bank of Upper Lias with its precipitous sides is continuous from the Peak Fault to Howedale Beck. Near the base of the Upper Lias the Jet Rock makes a conspicuous terrace; while the sandy series of the Middle Lias forms a still bolder terrace below, when not obliterated by drift. Though the outcrop of the Lower Lias cannot be actually seen, its position may be inferred by the steep bank which even the covering of drift cannot conceal; the base of this bank in the middle of the Bay being the hard marly bands of the zone of *Ammonites oxynotus*.

Eskdale is not cut to so great a depth in the Lias as Robin Hood's Bay, only 100 feet of Lower Lias being observed; but the symmetrical terraces can be well seen on the south side of the dale.

The general dip of the beds in the southern part of the map is south, with here and there a few local variations; but on the whole the geological structure is extremely simple. Upon reaching the middle of Robin Hood's Bay, however, the beds are observed to roll over and dip in a northerly direction, at a considerably greater rate than that at which they rose from the south; for, on reaching the cliff under Nype Howe, the Dogger is only 10 feet above high-water mark, so that the strata have dipped 750 feet in 2½ miles.

The effect of this change of dip can be very well seen on the edge of the moor over Park Hill, Robin Hood's Bay; on Ugglebarnby Moor, where the beds are lying almost flat; and in the great scar of Lower Lias shale, called Blue Scar, on the south bank of the Esk. Thus we have a great anticlinal axis running from the mouth of Mill Beck, Robin Hood's Bay, through the middle of Eskdale. The effect of this in Eskdale is very curious, as the beds really appear to dip east at the eastern half of the dale, and west at the western half; this appearance being caused by the valley crossing the anticlinal in an oblique direction. The beds dip west of north at Hawsker, to the east of north at Sneaton, and to the north at Rigg Mill. Again at Little Beck Alum Works the strata dip east, while at Kirk Moor Gate they are falling to the west. Thus we have a synclinal axis passing slightly east of Whitby, across Fylingdales Moor, and through Blea Hill Rigg, whose greater length being north and south can be accounted for by its lying in this trough.

There would seem to be an anticlinal axis slightly west of and parallel to the Peak Fault; the intersection of this and the great east and west anticlinal has doubtless caused the quaquaversal dip just inside the Bay, which the scars so beautifully illustrate.

Along the southern edge of the map there is also a well-marked synclinal axis, caused by the roll up of the beds mentioned in describing the country to the south, and with which anticlinal it is roughly parallel. This axis commences near the hamlet of Suffield, and ranges westwards by Hackness Hall, south of Broxa and Langdale End, and across Allerston Low Moors to the neighbourhood of Lockton and Levisham. South of this line the strata roll up and dip northerly for a short distance, so that the beds south of the Derwent at Hackness are at a higher level than those on the northern side of the river. It is owing to this synclinal axis that the unique section of the Coralline Oolite at Hackness has been preserved.

Faults.—There is only one large fault in the area included in this quarter sheet. Its exact position is clearly shown on the scars and in the cliff at the Peak, from which it is generally known as the Peak Fault. On the scars a triangular piece of rock may be observed, composed of hard sandy shale, containing *Cardium truncatum* in great abundance, which is evidently the top of the Sandy Series of the Middle Lias. The west edge of this scar is dipping 15° in an easterly direction; whilst in close proximity are soft grey micaceous shales containing *Ammonites densinodus, Belemnites elegans,* and *Gryphæa obliquata,* showing that these are the lowest of the *A. armatus* beds. The cliff immediately above these latter shales is 350 feet high, and the highest part of the cliff consists of the middle and lower part of the Sandy Series, of which the top is seen in the triangular scar. Hence, as the dip is inland, the throw of the fault is the total height of the cliff and the thickness of the beds brought under it by the dip, added to the small portion of the Sandy Series which has been denuded off the top of the cliff; that is to say, the throw of the fault seen on the west side of the triangular piece of rock is about 400 feet. On the east side of this triangle the Grey Shales and the top of the Ironstone Series are observed rising sharply seaward; hence the throw of the fault thus indicated is slightly more than the thickness of the Ironstone Series, *i.e.* nearly 100 feet. These two faults unite before reaching the shore; and the total throw of the combined fault is well seen some distance up the cliff, where the top of the Upper Lias is nearly level with the base of the Middle Lias, making the total throw a little over 400 feet. The hade is most clearly visible on the pathway down the Coomb, and a small spring issues along its line.

The direction inland is a little east of south, its position being well shown under Crag Hall, about half a mile inland, where the Dogger abuts against the Grey Limestone, the downthrow being somewhat less than 400 feet.

Its further course inland is difficult to determine accurately; indeed, the most obscure portion of the map is that about Staintondale, where the Peak Fault, in its passage to the south, breaks up the Lower Oolite in a manner which, from the nature of the rocks themselves and from the thick covering of Boulder Clay, is exceedingly difficult to make out. That the fault runs somewhere between Pye Rigg and Bell Hill* is evident; for at both of these places, which are nearly on the same line of strike, but have a difference of elevation of about 200 feet, fossils of the Grey

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* This spot is marked "Old Hall and Hospital" on the 1-inch map.

Limestone Series have been found. There also appears to be a break in the escarpment below the Whitby road, at a spot nearly a mile from the Falcon Inn, which is probably caused by a branch of this fault. The main branch of the fault, however, runs just west of Cloughton village; the Moor Grit being seen capping Ripleys Bank, from which it is thrown down 100 feet or more, so as to crop out in the upper part of the village. Whether this fault is continued further to the south there is no means of knowing, as the country is thickly covered with Boulder Clay, and the solid strata do not appear except on the coast. It is very probable that the dislocations about Scarborough may be a continuation of this fault; and the disturbance seen in the rocks south of Scalby Ness Point would seem to point to a possible connection.

The only other place where disturbed strata have been observed south of the Peak is at Hayburn Wyke, where there is a sharp anticlinal striking nearly north-west, which may be caused by a branch of the Peak Fault; but the evidence is not sufficient to warrant it being so mapped. The fault at Throxenby, mentioned in the description of the map to the south, also seems to have some connection with the western branch of this fault.

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Scale, one inch to a mile.

Anglesey, 78 (SW).
Bristol and Somerset, 19, 35.
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Clee Hill, 53 (NE, NW).
Denbighshire, 74 (NE & SE), 79 (SE).
Derby and Yorkshire, 71 (NW, NE, & SE), 82 (NW & SW), 81 (NE), 87 (NE, SE), 88 (SE).
Durham, 103, 105.
Flintshire, 79 (NE & SE).
Forest of Dean, 43 (SE & SW).
Forest of Wyre, 61 (SE), 55 (NE)
Lancashire, 80 (NW), 81 (NW), 89 (SE, NE, NW, & SW), 88 (SW, NW).
Leicestershire, 71 (SW), 63 (NW).
Northumberland and Durham (N. part), 105, 106 (SE), 109 (SW, SE).
North Staffordshire, 72 (NW), 72 (SW), 73 (NE), 80 (SE), 81 (SW).
South Staffordshire. 54 (NW), 62 (SW).
Shrewsbury, 60 (NE), 61 (NW & SW).
South Wales, 36, 37, 38, 40, 41, 42 (SE, SW).
Warwickshire, 62 (NE & SE), 63 (NW & SW), 54 (NE), 53 (NW).
Yorkshire, 88 (NE, SE), 87 (SW), 92 (SE), 93 (SW).

GEOLOGICAL MAPS.

Scale, six inches to a mile.

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17. Cartmel.
22. Aldingham.
47. Clitheroe.
48. Colne, Twiston Moor.
49. Laneshaw Bridge.
53. Whalley.
56. Haggate.
57. Winewall.
61. Preston.
62. Balderstone, &c.
63. Accrington.
64. Burnley.
65. Stiperden Moor.
69. Layland.
70. Blackburn, &c.
71. Haslingden.
72. Cliviger, Bacup, &c.
73. Todmorden.
77. Chorley.
78. Bolton-le-Moors.
79. Entwistle.
80. Tottington.
81. Wardle.
84. Ormskirk, St. Johns, &c.
85. Standish, &c.
86. Adlington, Horwick, &c.

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94. West Houghton, Hindley, Atherton
95. Radcliffe, Peel Swinton, &c.
96. Middleton Prestwich, &c.
97. Oldham, &c.
100. Knowsley, Rainford, &c.
101. Billinge, Ashton, &c.
102. Leigh, Lowton.
103. Ashley, Eccles.
104. Manchester, Salford, &c.
105. Ashton-under-Lyne.
106. Liverpool, &c.
107. Prescott, Huyton, &c.
108. St. Helen's, Burton Wood.
109. Winwick, &c.
111. Cheedale, part of Stockport, &c.
112. Stockport, &c.
113. Part of Liverpool, &c.

Durham.

1. Ryton.
2. Gateshead.
3. Jarrow.
4. S. Shields.

Durham—*continued.*

Sheet.
5. Greenside.
6. Winlaton.
7. Washington.
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11. Ebchester.
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41. Cockfield.
42. Bishop Auckland.
46. Hawksley Hill Hou
52. Barnard Castle.
53. Winston.

Northumberland.

44. Rothbury.
45 Longframlington.
46. Radcliffe and Broomhill.
47. Coquet Island.
54. Longhorsley.
55. Ulgham.
56. Druridge Bay, &c.
63. Netherwitton.
64. Morpeth.
65. Newbiggin.
72. Bedlington.
73. Blyth.
80. Cramlington.
81. Earsdon.
82.
83. Condley Gate.
87. Heddon-on-the-Wall.
88. Long Benton.
89. Tynemouth.
91. Greenhead.
92. Haltwhistle.
93. Haydon Bridge.
94. Hexham.
95. Corbridge.
96. Horsley.
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98. Walker.
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102. Allendale Town.
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109. Shotleyfield.
110. Wellhope.
111. Allenheads.
112.

Cumberland.

55. Scarness.
56. Skiddaw.
63. Thackthwaite.
64. Keswick.
65. Dockraye.
69. Buttermere.
70. Grange.
71.
74. Wast.
75. Stonethwaite Fell.
76.

Westmorland.

12. Patterdale.
25. Grasmere.
38. Kendal.

Yorkshire.

5. Romaldkirk.
7. Redcar.
9. ——
12. Bowes.
13. Wycliffe.
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276. Brodsworth.
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283. Wath upon Dearne.
284. Conisboroug
287. Low Bradfiel
288. Ecclesfield.
289. Rotherham.
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